

NOTICE

All drawings located at the end of the document.

BACKGROUND SOILS CHARACTERIZATION PROGRAM WORK PLAN

**Rocky Flats Plant
Golden, Colorado**

**U.S. DEPARTMENT OF ENERGY
Rocky Flats Plant
Golden, Colorado**

14 APRIL 1994

**EG&G Rocky Flats, Inc.
Golden, Colorado**

DRAFT

BACKGROUND SOILS CHARACTERIZATION PROGRAM WORK PLAN

**ROCKY FLATS PLANT
GOLDEN, COLORADO**

Prepared For:

**U.S. Department of Energy
Rocky Flats Plant
Golden, Colorado 80401**

Prepared By:

**EG&G Rocky Flats, Inc.
P.O. Box 464
Golden, Colorado 80402**

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LIST OF ACRONYMS

| | |
|--------|--|
| ANOVA | Analysis of Variance |
| ARAR | Applicable or Relevant and Appropriate Requirements |
| ASME | American Society of Mechanical Engineers |
| BSCP | Background Soils Characterization Program |
| CDH | Colorado Department of Health |
| CERCLA | Comprehensive Environmental Response, Compensation and Liability Act |
| CLP | Contract Laboratory Program |
| cm | Centimeter |
| COC | Contaminant of Concern |
| CRDL | Contract Required Detection Limit |
| CRQL | Contract Required Quantitation Limit |
| DMR | Document Modification Request |
| DOE | U.S. Department of Energy |
| DQO | Data Quality Objective |
| EDA | Exploratory Data Analysis |
| EG&G | EG&G Rocky Flats, Inc. |
| EMAD | Environmental Monitoring and Assessment Division |
| EMD | Environmental Management Department |
| EPA | U.S. Environmental Protection Agency |
| ER | Environmental Restoration |
| ft | Feet, Foot |
| FSP | Field Sampling Plan |
| GPS | Global Positioning System |
| GRRASP | General Radiochemistry and Routine Analytical Services Protocol |
| HASP | Health and Safety Plan |
| HPGe | High Purity Germanium Detector |

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LIST OF ACRONYMS (CONTINUED)

| | |
|-------|--|
| IAG | Rocky Flats Inter-Agency Agreement |
| IDL | Instrument Detection Limit |
| m | Meter |
| m/s | Meters Per Second |
| MDL | Maximum Detection Limit |
| mi | Mile |
| MLE | Maximum Likelihood Estimate |
| mph | Miles per Hour |
| M&TE | Measuring and Test Equipment |
| ND | Non-Detected |
| OP | Operating Procedure |
| OSWER | Office of Solid Waste and Emergency Response |
| OU | Operational Unit |
| PAH | Polynuclear Aromatic Hydrocarbon |
| PARCC | Precision, Accuracy, Representativeness, Comparability, and Completeness |
| PCB | Polychlorinated Biphenyl |
| QA | Quality Assurance |
| QAA | Quality Assurance Addendum |
| QAMS | Quality Assurance Management Staff |
| QAPjP | Quality Assurance Project Plan |
| QAPM | Quality Assurance Project Manager |
| QC | Quality Control |
| RCRA | Resource Conservation and Recovery Act |
| RF | Rocky Flats |
| RFEDS | Rocky Flats Environmental Database System |
| RFI | RCRA Facility Investigation |
| RFP | Rocky Flats Plant |

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LIST OF ACRONYMS (CONCLUDED)

| | |
|------|---|
| RI | Remedial Investigation |
| RMSE | Root Mean Squared Error |
| RPD | Relative Percent Difference |
| SCS | Soil Conservation Service |
| SOP | Standard Operating Procedures |
| TAL | Total Analyte List |
| TCL | Target Compound List |
| USDA | United States Department of Agriculture |
| USGS | United States Geological Survey |



EXECUTIVE SUMMARY

This work plan describes and establishes a program for the characterization of background soils for the Rocky Flats Plant (RFP). The plan describes how data representative of RFP background in soils will be collected and analyzed using a number of statistical techniques. Background soil information will provide baseline data for other environmental programs that monitor for potential contaminant releases.

Development of this work plan followed the U.S. Environmental Protection Agency's (EPA's) data quality objectives (DQOs) process and included a detailed review and analysis of existing investigations. Previous investigations were reviewed and documented to aid in the identification of data needs and to guide development of a sampling design plan. Two data needs were identified which include (1) additional background surface soil information, and (2) background soil profile information.

For surface soils, an exploratory data analysis (EDA) was performed to provide a rationale for the spatial distribution and number of sampling locations. The EDA resulted in the following conclusions:

- For fallout radionuclides, a remote (off-site) sampling program at locations along the Colorado Front Range physically similar to RFP is appropriate to characterize background conditions in surface soils. The analysis indicated that approximately 50 samples were necessary to adequately characterize background for fallout radionuclides.
- For naturally-occurring radionuclides, metals, and semivolatile organic compounds, a sampling program in the vicinity of the Rock Creek Drainage north of RFP is appropriate to augment existing background surface soil data. The analysis indicated that approximately 20 additional samples were appropriate to characterize background for these constituents.

With regard to soil profiles, the need for additional data in background areas was identified to provide the following information:

- Distribution of analytes in genetic horizons
- Physical/chemical/mineralogical/biological parameters in genetic horizons
- Soil ecological and pedological data.

Quality assurance (QA) measures and procedures for analysis and reporting of the information collected have been documented in this work plan. As set forth in this work plan, field sampling is currently scheduled to begin in May, 1994. A final report for the surface soil sampling program will be produced during Summer, 1995 and a final report for the soil profile program will be produced during Fall, 1995.

1.0 INTRODUCTION

This work plan describes the staged development of the Rocky Flats Plant (RFP) Background Soils Characterization Program (BSCP). The work plan contains nine sections: Introduction, Physical Setting, Previous Investigations, Data Quality Objectives (DQOs), Field Sampling Plan, Data Interpretation and Reporting, Quality Assurance (QA) Addendum, Schedule, and Bibliography.

1.1 BACKGROUND

RFP is a government-owned, contractor-operated facility, and was part of the nationwide nuclear weapons production complex.

The historical mission of RFP was to fabricate nuclear weapons components from plutonium, uranium, and nonradioactive metals (principally beryllium and stainless steel). Additionally, the plant reprocessed plutonium that was removed from obsolete weapons. Both radioactive and nonradioactive wastes were generated at the plant. Present waste-handling practices involve recycling of hazardous materials, on-site storage of hazardous, radioactive, and mixed wastes, as well as off-site disposal of radioactive materials. Preliminary assessments under the Environmental Restoration (ER) Program identified some of the past on-site storage and disposal locations as potential sources of environmental contamination.

RFP is in transition from a weapons production site to an environmental and waste management site. The activities underway at RFP are consistent with down-sizing and consolidation of the DOE weapons complex. A Transition Team consisting of EG&G Rocky Flats, Inc. (EG&G) and U.S. Department of Energy (DOE) personnel is leading these efforts.

The RFP ER Program is part of the national DOE ER Program, which was established to remediate inactive waste sites at DOE facilities. The DOE ER Program is mandated to remediate waste sites in compliance with environmental laws and regulations, while maintaining human health and safety as well as protecting the environment. Specifically, the program includes site identification and characterization, remedial design and remedial action, and post-closure activities such as monitoring and field inspections at inactive radioactive, hazardous, and mixed-waste sites. This task directly supports the ER Program by providing baseline information for these activities.

1.2 PURPOSE

The purpose of this plan is to establish a program for the characterization of selected background soil parameters at RFP. The plan describes how data representative of RFP background will be collected and analyzed. Reasons for implementing the RFP BSCP follow:

- Background soil data will provide a baseline against which soil data for Resource Conservation and Recovery Act (RCRA) Facility Investigation (RFI)/Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) Remedial Investigation (RI) may be compared for identifying contamination at RFP operable units (OUs). These data may also be used in establishing reasonable remediation goals and justifying a waiver for complying with Applicable or Relevant and Appropriate Requirements (ARARs) and to provide a benchmark in assessing environmental and human health risks due to contamination at RFP.
- The BSCP is a requirement of the RFP Interagency Agreement (IAG), a legal agreement between the State of Colorado, represented by the Colorado Department of Health (CDH), U.S. Environmental Protection Agency (EPA), and the DOE.
- The BSCP contributes to the geochemical characterization of the RFP site as mandated by DOE Order 5400.1.
- Background soil chemistry and physical properties data will supplement other site-wide soil characterization studies and provide a baseline for other environmental programs that monitor for potential contaminant releases.

For the purposes of the BSCP, the term "background" must be defined. The EPA definitions (EPA, 1989a) are: (1) "natural background" - ambient concentrations of chemicals present in the environment uninfluenced by human activities; and (2) "anthropogenic background" - concentrations of chemicals consistently present in the environment because of human-made, non-site-specific sources (i.e. wide spread agriculture practices, automobiles, world-wide fallout levels, etc.). To distinguish contaminants that were produced by activities at RFP from contaminants present due to widespread human contamination, anthropogenic background will be used to define "background" in this study. Background soil chemistry may be influenced by non-RFP anthropogenic sources. These anthropogenic background sources have been considered in the Field Sampling Plan (Section 5.0).

Because previous investigations have not adequately delineated or characterized background soil conditions, additional characterization is needed for the following reasons.

- Historic background data collection prior to 1990 focused primarily on plutonium. Some of those historic sampling efforts may not have used consistent sampling methodologies useful for establishing a background database needed for RCRA/CERCLA decisions regarding plutonium contamination at the RFP. In addition to plutonium data, background data is needed for other potential contaminants of concern.
- Currently, a clustered data set of 18 sample locations within the RFP buffer zone in the Rock Creek drainage (the Rock Creek data set) is being used for OU RCRA/CERCLA decisions regarding background surface soil data. An exploratory data analysis (EDA) of all available historic data in and around RFP, discussed in Section 4.3 of this work plan, indicates that data are not sufficient to determine if the Rock Creek data set is located in an area unaffected by the RFP for plutonium. Although the EDA indicates that the Rock Creek data set is located in an area unaffected by RFP for other potential contaminants of concern, an additional minimum of 17 samples needs to be collected to augment that data set for non-plutonium analytes.
- Correspondence among DOE, CDH, EPA, and EG&G has indicated the need for off-site sampling of surface soils.
- Chemical, physical, and mineralogical characterization of soil horizons in major soil groups has not been investigated in previous background soil characterization efforts. This information supports ongoing site-wide soils characterization studies (Litaor, 1993a).

Two unique studies will be conducted under this plan to characterize RFP background soils. Chemical characterization of the top five centimeters (cm) [two inches (in)] of soil in undisturbed areas is necessary to support RCRA/CERCLA decisions. Chemical, physical, and mineralogical characterization of the upper 1.2 meters (m) [3.9 feet (ft)] of soil material in undisturbed areas supports sitewide soils characterization efforts. These two studies of RFP background soils supplement previous background characterizations of groundwater, surface water, sediment, and geologic materials (EG&G, 1993a).



2.0 PHYSICAL SETTING

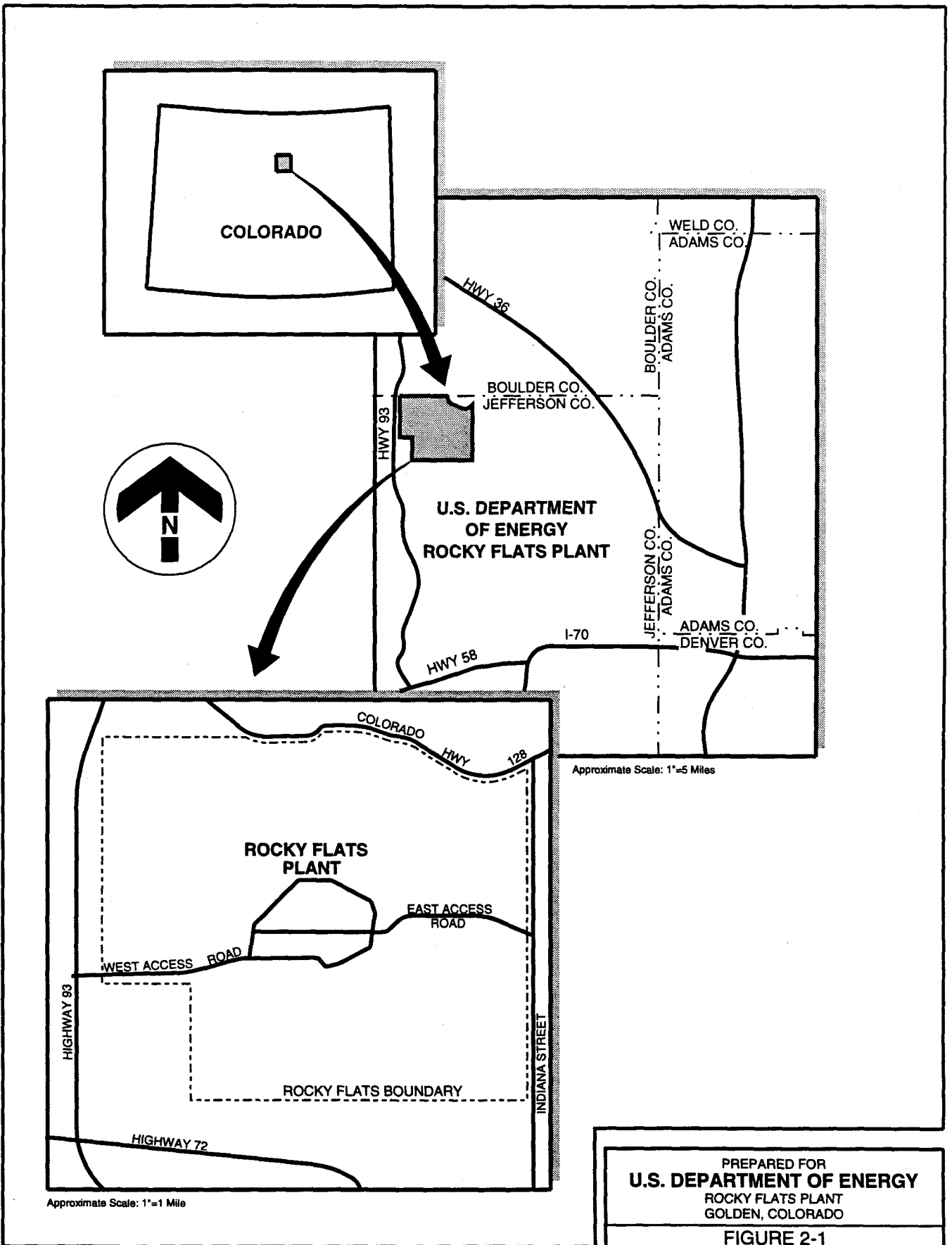
An understanding of the overall physical setting of RFP and adjacent environs is important to successful project scoping and implementation. RFP is located in northern Jefferson County, Colorado, approximately 26 kilometers (km) [16 miles (mi)] northwest of Denver (Figure 2-1). Other surrounding cities include Arvada, Boulder, and Westminster, which are located less than 16 km (10 mi) to the southeast, northwest, and east, respectively. RFP consists of approximately 2650 hectares (ha) (6,550 acres) of federally owned land in Sections 1 through 4 and 9 through 15 of T2S, R70W, 6th Principal Meridian. Major buildings are located within the RFP security area of approximately 162 ha (400 acres). The security area is surrounded by a buffer zone of approximately 2,490 ha (6,150 acres) (Figure 2-2).

The remainder of this section presents a discussion of the following elements of the site physical setting:

- Topography
- Surface Water Hydrology
- Geology
- Hydrogeology
- Meteorology and Climatology
- Sitewide Soils.

2.1 TOPOGRAPHY

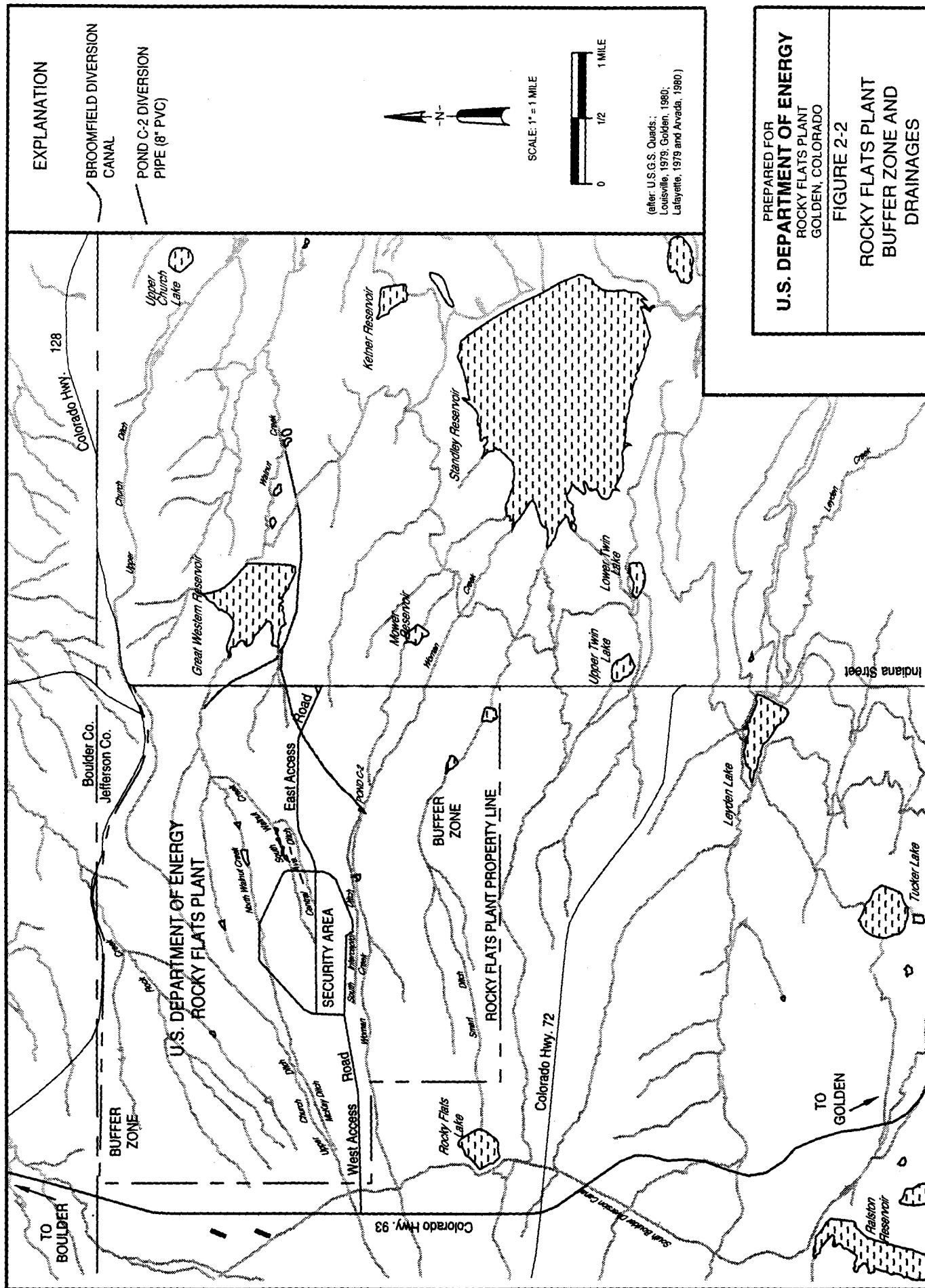
The natural environment of RFP and vicinity is influenced primarily by its proximity to the Front Range of the Rocky Mountains. RFP is directly east of the north-south trending Front Range, and is located about 26 km (16 mi) east of the Continental Divide at an elevation of approximately 1,830 m (6,000 ft) above mean sea level. RFP is located on a broad, eastward sloping plain of coalescing alluvial fans developed along the Front Range. The fans extend about eight km (five mi) in an eastward direction from their origin at Coal Creek Canyon and terminate on the east at a break in slope to low rolling hills. The operational area at the RFP is located near the eastern edge of the fans on a terrace between stream-cut valleys (North Walnut Creek and Woman Creek).



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GOLDEN, COLORADO

FIGURE 2-1

**GENERAL LOCATION OF
ROCKY FLATS PLANT**



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 ROCKY FLATS PLANT
 GOLDEN, COLORADO

FIGURE 2-2
 ROCKY FLATS PLANT
 BUFFER ZONE AND
 DRAINAGES

2.2 SURFACE WATER HYDROLOGY

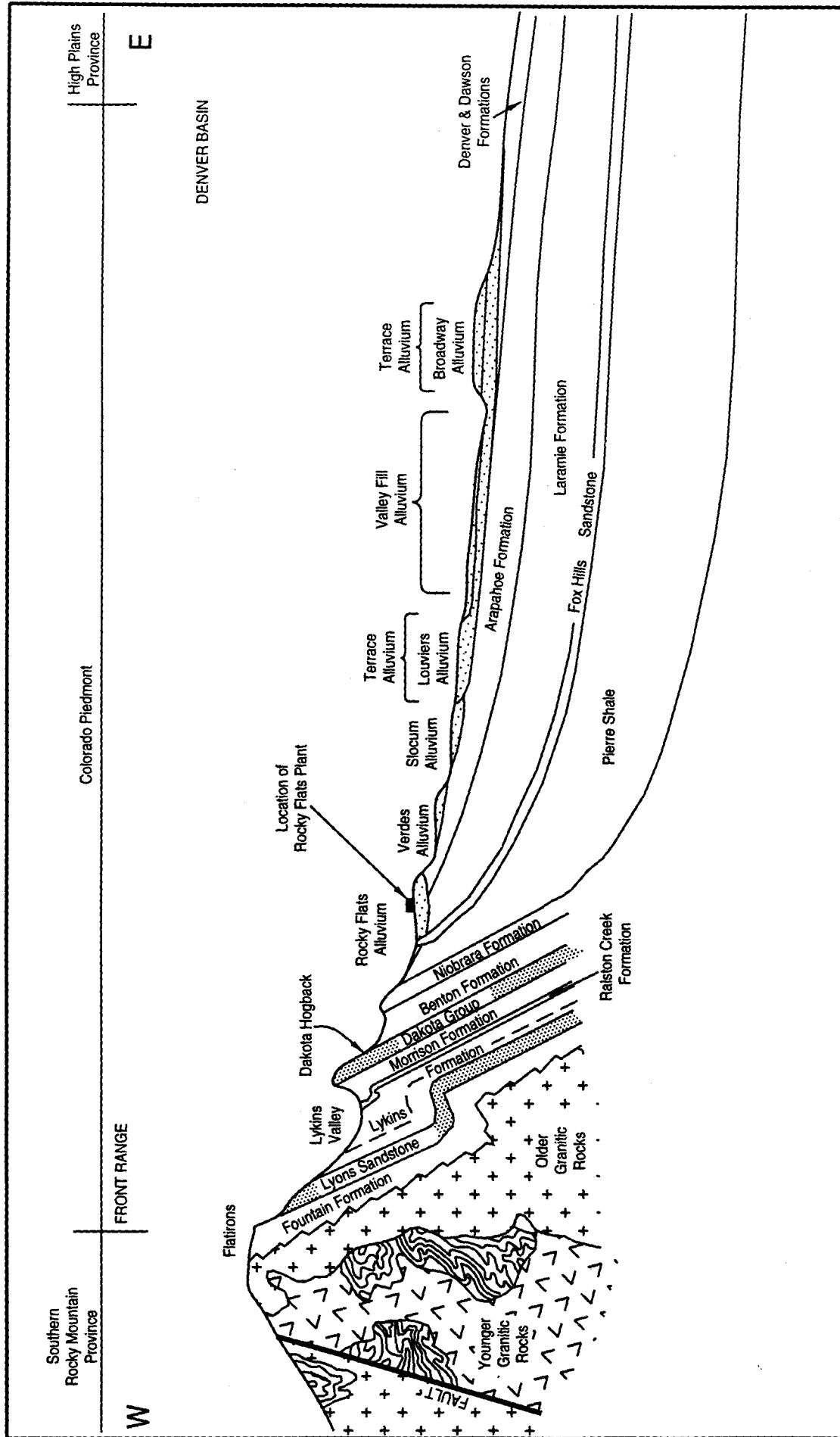
Three intermittent streams drain RFP with flow generally from west to east. These drainages are Rock Creek, Walnut Creek, and Woman Creek (Figure 2-2). Rock Creek drains the northwestern corner of the RFP and flows northeast through the buffer zone to its off-site confluence with Coal Creek. An east-west trending interfluvial separates the Walnut Creek and Woman Creek drainages. North and South Walnut Creeks and an unnamed tributary drain the northern portion of the RFP security area. These three forks of Walnut Creek join in the buffer zone and flow toward Great Western Reservoir, which is approximately 1.6 km (one mi) east of the confluence. However, this flow is routed around Great Western Reservoir by the Broomfield Diversion Canal, which is operated by the City of Broomfield. Woman Creek drains the southern RFP buffer zone flowing eastward. The Woman Creek flow is diverted onsite to Mower Reservoir via the Mower Ditch. The South Interceptor Ditch lies between RFP and Woman Creek. The South Interceptor Ditch collects runoff from the southern RFP security area and diverts it to Pond C-2 where it is monitored, treated and then pumped to the Walnut Creek watershed where it is released to the Broomfield Diversion Canal.

2.3 GEOLOGY

Geologic units beneath RFP consist of unconsolidated surficial units of Quaternary age (Rocky Flats Alluvium, various terrace alluvia, valley fill alluvium, and colluvium), which unconformably overlie Cretaceous-aged bedrock (Arapahoe Formation, Laramie Formation, and Fox Hills Sandstone) (Figure 2-3). This geologic sequence forms part of a monoclinical fold whose western edge is composed of uplifted strata of Mesozoic age that become younger to the east. Figure 2-4 shows the surficial geology of the RFP (EG&G, 1992) and Figure 2-5 depicts the erosional surfaces and alluvial deposits in cross-section.

2.4 HYDROGEOLOGY

Two groundwater flow systems are distinguished in the current conceptual model of the subsurface hydrology of RFP. The upper flow system is unconfined and lies within the Rocky Flats Alluvium, colluvium, valley-fill alluvium, and weathered bedrock. The lower flow system is confined within unweathered bedrock sandstones of the lower Arapahoe and upper Laramie Formations. The two flow systems are probably in hydraulic connection where bedrock sandstone subcrops under surficial materials. Recharge to the unconfined flow system is from precipitation, snowmelt, and water losses from ditches, streams, and ponds. Groundwater movement in both flow systems is generally from west to east.



Not to Scale

Source: Boulder County Planning Commission, 1983 and Scott, 1960

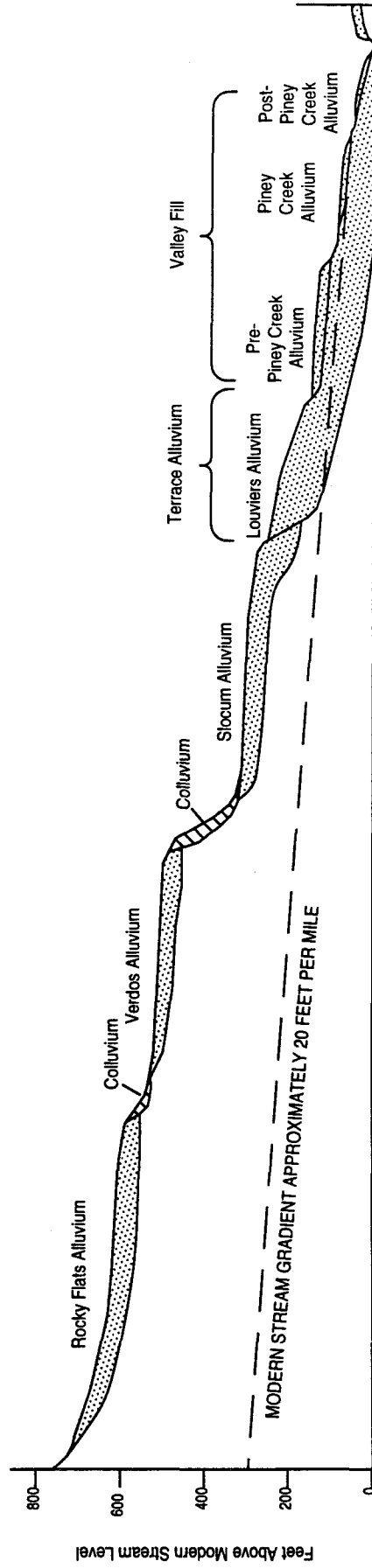
| | |
|---|--|
| PREPARED FOR U.S. DEPARTMENT OF ENERGY ROCKY FLATS PLANT GOLDEN, COLORADO | FIGURE 2-3 GENERALIZED EAST-WEST CROSS-SECTION FRONT RANGE TO DENVER BASIN |
|---|--|



WEST

ROCKY FLATS PLANT SITE

EAST



NOT TO SCALE

Source: Scott, 1960

PREPARED FOR
U.S. DEPARTMENT OF ENERGY
ROCKY FLATS PLANT
GOLDEN, COLORADO

FIGURE 2-5
EROSIONAL SURFACES AND
ALLUVIAL DEPOSITS EAST OF
THE COLORADO FRONT RANGE

Groundwater levels in the upper flow system rise in response to recharge during the spring and decline during the remainder of the year. During periods of high surface water flow, water is lost to bank storage in the valley-fill alluvium and returns to the stream after the runoff subsides. In the western portion of RFP, where the thickness of the alluvial material is greatest, the depth to the water table is 15 to 21 m (50 to 70 ft) below the surface. The water table becomes shallower to the east (with local variations) as the alluvial material thins.

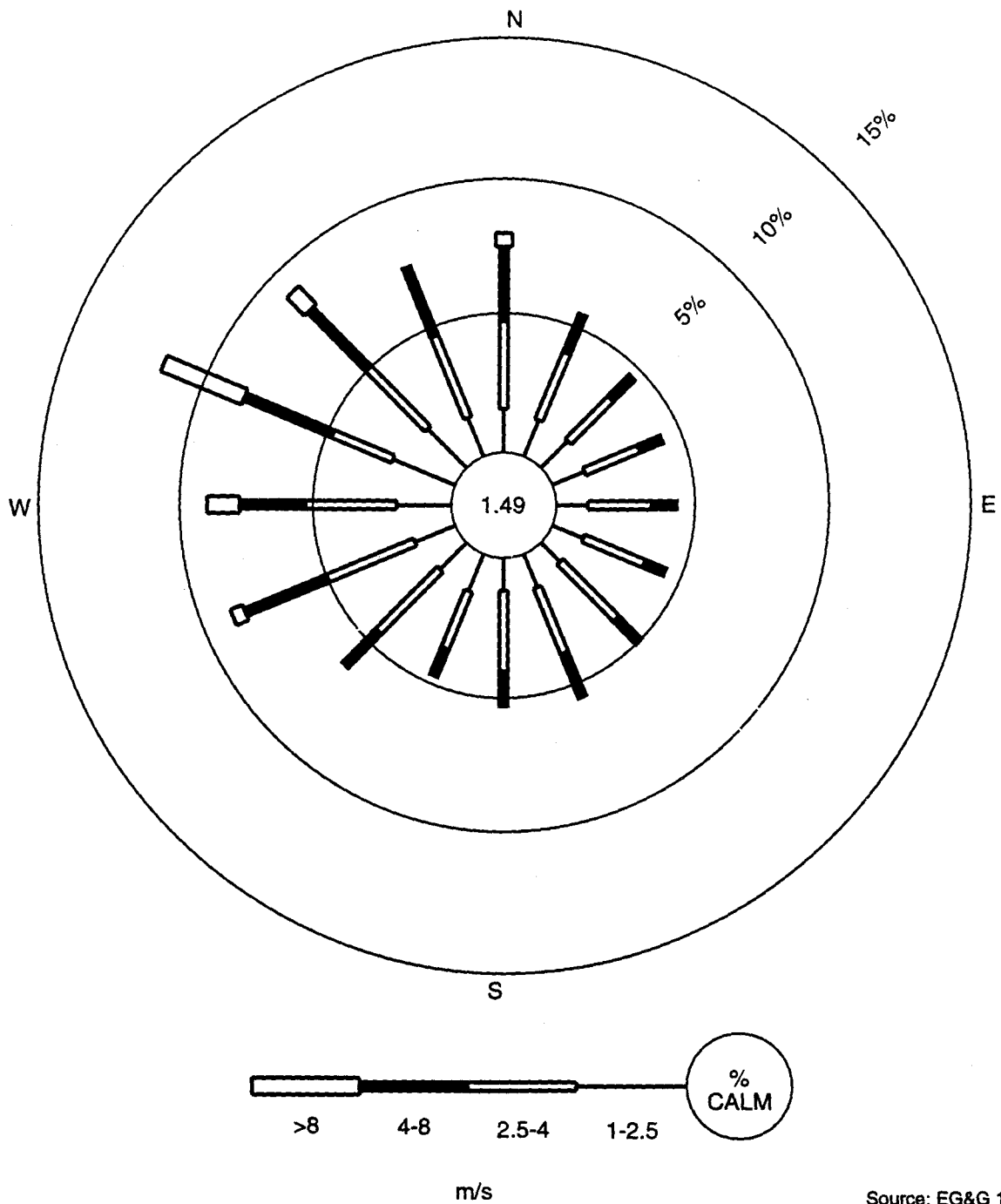
2.5 METEOROLOGY AND CLIMATOLOGY

The area surrounding RFP has a semiarid climate characteristic of much of the central Rocky Mountain region. Approximately 40 percent of the 38 cm (15 in) annual precipitation falls during the spring season, much of it as snow. Thunderstorms (June to August) account for an additional 30 percent of the annual precipitation. Autumn and winter are drier seasons, accounting for 19 and 11 percent of the annual precipitation, respectively. Snowfall averages 85 inches per year, falling from October through May (DOE, 1980). Temperatures are moderate; extremely warm and cold weather is usually of short duration. On the average, daily summer temperatures range from 13 degrees Celsius (13° C) to 29° C [55° Fahrenheit (55° F) to 85° F], and winter temperatures range from -6.7° to 7.2°C (20° to 45°F). The low average relative humidity (46 percent) is due to the moisture-blocking effect of the Rocky Mountains. Wind, temperature, and precipitation data are collected on the plant site and summarized annually. Figure 2-6 illustrates a typical annual summary of wind velocity and frequencies occurring at the RFP. Winds at the RFP are predominantly northwesterly. Winds greater than three meters per second (m/s) [6.7 miles per hour (mph)] with easterly components occur with a low frequency.

Special attention has been focused on dispersion meteorology surrounding the plant due to the possibility that significant atmospheric releases might affect the Denver metropolitan area, located in the predominant downwind direction (southeast). Studies of air flow and dispersion characteristics (e.g., Hodgin, 1983, 1984) indicate that drainage flows from the mountains to the west, turns and moves toward the north and northeast along the South Platte River valley and passes to the west and north of Brighton, Colorado (DOE, 1980), which is just north of Denver.

2.6 SITEWIDE SOILS

Soils of the RFP site occur in a predictable pattern related to geologic parent materials, geomorphic landforms, relief, climate, and natural vegetation. Recognizing the relationships between types of soils and particular types of landscapes or segments of landscapes over a broad



Source: EG&G 1992

PREPARED FOR
U.S. DEPARTMENT OF ENERGY
ROCKY FLATS PLANT
GOLDEN, COLORADO

FIGURE 2-6
WIND ROSE FOR THE
ROCKY FLATS PLANT
1992-24 HOUR

region that surrounds the RFP site area, the United States Department of Agriculture (USDA) Soil Conservation Service (SCS) developed map unit models on aerial photographs to reasonably predict the kinds of soils in an area. The boundaries of the map units were refined and the map unit models tested by digging test pits and recording the characteristics of the soil profiles studied.

A soil can be taxonomically classified, based on a particular set of soil properties (such as number and size of clasts, particle size distribution, acidity, distribution of plant roots, structure of soil aggregates, etc.) and the arrangement of horizons within the soil profile. The soil taxonomic system is hierarchical, enabling categorization into increasingly greater detail. The soil taxonomic system in increasing level of detail is order, suborder, great group, subgroup, and series. Figure 2-7 illustrates the SCS soil map units at the soil series level. Figure 2-8 illustrates soils at the subgroup level, modified by particle size and depth class.

Soil series within a landscape type at RFP are similar at the subgroup level. Soils of the RFP site are forming in association with the following four general landscape types and geologic map units.

- Pediment soils located on the broad, dissected, eastward sloping pediment surface in the western portion of the site. These soils are associated with the Rocky Flats Alluvium geologic map unit (Qrf).
- Valley slope soils located in the stream-cut valleys of the intermittent Rock Creek, Walnut Creek, and Woman Creek drainages. These are associated with the Laramie Formation (Kl), Arapahoe Formation (Ka), and Landslide (Qls) geologic map units.
- Hill soils of the eastern third of RFP. These soils are similar to Valley Slope soils and are associated with the Laramie (Kl) and Arapahoe (Ka) Formations. Localized areas on hill summits are associated with Terrace Alluvium (Qta).
- Drainage bottom soils. These soils are forming in recent alluvium (Qa) along drainage bottoms.

Each of these landscape- and geology-associated soils are discussed and summarized in the following subsections.

2.6.1 Pediment Soils

The gently sloping (five percent slope or less) pediment surface is dominated by the deep, well drained, Flatirons soil series with a minor inclusion of the Valmont soil series occurring in the northeast corner of RFP. These soils are strongly developed soils that are forming in the Rocky Flats Alluvium (Qrf), the oldest and highest Pleistocene alluvium in the Denver area. Rocky Flats Alluvium was formed by a series of coalescing alluvial fans deposited by braided streams originating from the mouth of Coal Creek Canyon approximately five miles west of the RFP site.

Typically, the Flatirons soils (clayey-skeletal Aridic Paleustolls) have a very cobbly, dark-brown surface horizon (A horizon), approximately 33 cm (13 in) thick, overlying a very gravelly, clay-rich, reddish-brown to dark red argillic horizon (Bt horizon). The Bt horizon is 76 to 150 cm (30 to 60 in) thick in the western portion of RFP, thinning to about 30 cm (12 in) thick at the eastern extent of the Flatirons soil. A discontinuous, calcium rich K horizon (caliche) underlies the Bt horizon in places. The Flatirons soil extends to a depth of 150 cm (60 in) or greater. As much as 15 percent of the pediment surface may be made up of inclusions of soils other than the Flatirons soils or disturbed land.

Soils forming on a distal reach of the Rocky Flats Alluvium pediment in the northeastern corner of the plant are of the Valmont series. The Valmont soils (loamy-skeletal, Aridic Argiustolls) are similar to the Nederland series described in Section 2.6.2.

2.6.2 Valley Slope Soils

Valley slopes include downslope mass movements of rocky material from the pediment surface and fine-textured material from the underlying claystone, siltstone, and sandstone bedrock of the Arapahoe (Ka) and Laramie (Kl) Formations, which have been exposed by stream cutting processes.

Soils forming in colluvium along the relatively narrow band of steep (15- to 60-percent slopes) upper portions of the valley slopes are mapped predominantly as the deep, well drained Nederland series. Nederland soils (loamy-skeletal Aridic Argiustolls) typically occur in

colluvium or landslide deposits that are dominated by clast-rich materials from the Rocky Flats Alluvium. Nederland soils are similar to Flatirons soils; however, Nederland soils generally have less clay in the soil matrix and are not typically underlain by a calcium-rich lower horizon.

Soils forming in colluvium and landslide deposits below the shoulder of the pediment escarpment (9- to 25-percent slopes) are mapped as the Denver-Kutch-Midway complex. Denver soils (fine, Torrtic Argiustolls) are deep, well-drained, fine textured soils. Typically, the A horizon is a grayish-brown clay loam, 15 to 36 cm (6 to 14 in). The argillic Bt horizon is a clay, 15 to 36 cm (6 to 14 in) thick. A calcium-rich and clay-rich K horizon extends to depths of 150 cm (60 in) or greater. Kutch soils (fine, Torrtic Argiustolls, moderately deep) are similar to Denver soils; however, the depth of Kutch soils is between 51 and 102 cm (20 and 40 in), to a contact with weathered claystone bedrock. Midway soils (clayey, shallow, Ustic Torrtic) are formed where claystone bedrock is exposed or very near the surface. Midway soils are weakly developed soils of the soil order Entisol. Midway soils typically have a thin A horizon, usually 7.6 cm (three in) or less thick and a total depth to weathered bedrock of less than 51 cm (20 in).

Included in the Denver-Kutch-Midway complex and in the Nederland map unit are other soils that may make up as much as 15 percent of each map unit. Some of these inclusions may be composed of wet soils associated with seeps and springs located on the valley slopes.

2.6.3 Hill Soils

For the most part, hill soils are similar to valley slope soils described earlier. These soils are forming on the hill-like terrace summits, and the slopes, fans, and ridges of the rolling topography in the eastern third of the plant site in Laramie (Kl) and Arapahoe (Ka) Formations and in small areas of Terrace Alluvium (Qta).

Soils forming on the hill-like terrace summits (0- to 5-percent slopes) in the southeastern portion of RFP are of the Nunn series and the Standley series. Nunn soils (fine, Aridic Argiustolls) are similar to Denver soils (fine, Torrtic Argiustolls) except that the Torrtic subgroup (Denver) has a more pronounced shrinking and swelling capability than the Aridic subgroup. Standley soils are similar to Nunn soils (fine, Aridic Argiustolls); however, the Standley soils contain more gravel than Nunn soils.

Soils forming on the upper hill slopes (5- to 15-percent slopes) of the southeastern corner are Denver-Kutch soils described earlier.

Soils forming on hill slopes (15- to 50-percent slopes) of the northeastern corner of the plant are of the Leyden-Primen-Standley complex, which is analogous to the Denver-Kutch-Midway complex. The Leyden-Primen-Standley complex is of the Aridic subgroup of Argiustolls and therefore have less pronounced shrinking and swelling capabilities than the Torrertic subgroup of the Denver-Kutch-Midway complex.

2.6.4 Drainage Bottom Soils

Drainage bottom soils forming in loamy, stratified alluvium from mixed sources in floodplains (0- to 3-percent slopes) are predominantly the Haverson series. Haverson soils (fine-loamy Ustic Torrifluvents) are deep, well-drained, weakly developed soils of the order Entisol. Typically, the Haverson soil has a thin A horizon, 15 cm (6 in) thick, overlying a stratified clay loam and gravelly loam about 102 cm (40 in) thick. Below that may be a layer of stratified, very gravelly loamy sand to a depth of 150 cm (60 in) or more.

Soils forming in poorly drained areas on valley floors and in floodplains are the McClave series. McClave soils (fine-loamy, Cumulic Haplaquolls) are deep, somewhat poorly drained "wet" soils of the order Mollisol. Typically, the surface-layer A horizons are dark-brown clay loams, about 30 to 36 cm (12 to 14 in) thick. The next horizon is a brown clay loam [to a depth of 107 cm (42 in)], which exhibits color mottling due to alternating oxidizing and reducing conditions. The substratum is a brown, sandy clay loam [to 150 cm (60 in) or greater], which also exhibits mottling.

Soils forming in well-drained stream terraces slightly higher than the floodplain are the Englewood series. The Englewood soils (fine, Torrertic Argiustolls) are similar to Denver soils. Included with the drainage bottom soils are soils similar to McClave, Englewood, and Haverson soils, but which have greater than 35-percent rock fragments in the soil layers.

2.6.5 Soil Summary

Table 2-1 summarizes the soil series and taxonomic classifications with their associated landscape types and geologic formations. A comparison between the geologic map and Figure 2-7 illustrates the association between soils at the subgroup level and geologic map units; this association will be utilized to describe the sampling design outlined in Subsection 5.2.

TABLE 2-1

SOIL TAXONOMIC TABLE

| ORDER | SUBORDER | GREAT GROUP | SUBGROUP | CLASS MODIFIER | SERIES | GEOLOGY | LANDSCAPE | SIMILAR GROUP |
|----------|----------|--------------|-----------|-----------------|-----------|-------------|-----------------|---------------|
| Mollisol | Ustoll | Paleustoll | Aridic | clayey-skeletal | Flatirons | Qrf | Pediment | 1 |
| | | | | loamy-skeletal | Nederland | Kl, Ka, Qls | Valley slope | 2 |
| | | Argiustoll | Aridic | | Valmont | Qrf | Pediment (East) | 2 |
| | | | | fine | Nunn | Qta | East hillslopes | 3 |
| | | | | fine | Standley | Ka, Kl, Qls | East hillslopes | 3 |
| | | | | fine, mod. deep | Leyden | Ka, Kl, Qls | East hillslopes | 3 |
| | | | | clayey, shallow | Primen | Ka, Kl, Qls | East hillslopes | 3* |
| | | | Torreptic | fine | Denver | Ka, Kl, Qls | Valley slope | 3 |
| | | | | fine | Englewood | Ka, Kl, Qa | Valley toeslope | 3 |
| | | | | fine, mod. deep | Kutch | Ka, Kl, Qls | Valley slope | 3 |
| Entisol | Aquoll | Haplaquoll | Cumulic | fine-loamy | McClave | Qa, Kl | Drainage bottom | 4 |
| | Fluvent | Torrifluvent | Ustic | fine-loamy | Haverson | Qa, Kl | Drainage bottom | 4 |
| | Orthent | Torriorthent | Ustic | clayey, shallow | Midway | Ka, Kl, Qls | Valley slope | 3* |

Note: 3* The shallow soils (Primen and Midway series) have been included as similar to Group 3 soils because they occur with Group 3 soils and are not easily mapped separately.

3.0 PREVIOUS INVESTIGATIONS

Numerous investigations have been conducted to characterize environmental media and assess the extent of radiological and chemical contaminant releases to the environment. Results from these studies (i.e., chemical data) were compiled to gain knowledge regarding radiological and chemical variability for background areas in the general region of RFP.

Data from previous investigations were used for the following purposes:

- To provide an understanding of contaminant release and distribution patterns at RFP
- To help identify potential data gaps
- To aid in designing the sampling plan.

This section summarizes the information from previous investigations for each of the BSCP analyte groups of interest (radionuclides, metals, semivolatile organic compounds, and soil profile data) and discusses surface soil sampling methodologies. Table 3-1 presents a compilation of previous investigations obtained to date for radionuclides, metals, and organic compounds.

3.1 RADIONUCLIDES

This section summarizes data evaluated from previous investigations for radionuclides in soils. The radionuclides of interest to the BSCP include those radionuclides which were produced as a result of activities at RFP, certain of the "daughter" or decay products of those radionuclides, and other radionuclides, such as ¹³⁷Cesium (Cs). Regional studies and site-specific studies related to the potential influence from RFP have been compiled and are presented in Table 3-1. Appendix A presents spatial information relative to these previous studies.

Radionuclides found in background soils (i.e. soils in areas not influenced by RFP or other site-specific sources) are present either because they are derived from natural materials in the earth's crust, or because they have been distributed by nuclear weapons fallout over the earth's surface. The fallout radionuclides group includes ^{239/240}Plutonium (Pu), ²⁴¹Americium (Am), ¹³⁷Cs, and ^{89/90}Strontium (Sr). The naturally occurring radionuclides group includes ^{233/234}Uranium (U), ²³⁵U, ²³⁸U, ²²⁶Radium (Ra), and ²²⁸Ra. Table 3-2 provides ranges of radionuclide soil concentrations, other than Pu, from regional investigations, and Table 3-3 provides those ranges for investigations at or nearby RFP.

TABLE 3-1

SUMMARY OF PREVIOUS INVESTIGATIONS

| STUDY | DATA TYPE | OBJECTIVE | POTENTIAL DATA USE |
|--------------------------------|------------------------|--|--|
| Lowder et al. (1964) | U, Th | Determine natural radioactivity in soils | Interpretation of BSCP soil data against regional values |
| Krey and Hardy (1970) | Pu | Quantify Pu inventory on-site and off-site, define maximum distances from plant at which RFP Pu could be detected | Used for exploratory data analysis (Section 4.3) |
| Seed et al. (1971) | Pu | Assess the long-term potential hazard of Pu-contaminated soil under and around the 903 Pad at RFP | Used for exploratory data analysis |
| Poet and Martell (1972) | Pu, Sr, Am | Determine extent of Pu in soils, surface waters and sediments in off-site areas surrounding RFP | Used for exploratory data analysis |
| Loser and Tibbals (1972) | Pu | Analyze areal extent of Pu east of Indiana Avenue | Used for exploratory data analysis |
| Michels | Pu, Cs | Relate depositional processes to geographical fallout patterns in the U.S. Great Plains | Interpretation of BSCP soil data against regional values |
| Hardy (1976) | Pu, Cs | Determine deposition patterns from detonations conducted at the Nevada Test Site (NTS) | Interpretation of BSCP soil data against regional values |
| Illsley and Hume (1979) | Pu | Answer claims against RFP claiming radionuclide depositions from RFP on adjacent lands caused these lands to be unfit for human habitation and use | Used for exploratory data analysis |
| Perkins and Thomas (1980) | radionuclides | Synthesize research literature | Interpretation of BSCP soil data against regional values |
| Myrick et al. (1983) | Ra, Th, U | Determine background concentrations in surface soils | Interpretation of BSCP soil data against regional values |
| Shacklette and Boerngen (1984) | metals, U, Sr, Th | Identify concentrations in surficial soils of the conterminous U.S., geographical variations | Interpretation of BSCP soil data against regional values |
| Eisenbud (1987) | radionuclides | Provide overview of environmental radioactivity, synthesis of research literature | Interpretation of BSCP soil data against regional values |
| ORNL - Holleman et al. (1987) | Pu | Synthesis of literature for worldwide fallout levels | Interpretation of BSCP soil data against regional values |
| Dragun (1988) | metals, semi-volatiles | Synthesis of research literature | Interpretation of BSCP soil data against regional values |

TABLE 3-1 (CONCLUDED)

SUMMARY OF PREVIOUS INVESTIGATIONS

| STUDY | DATA TYPE | OBJECTIVE | POTENTIAL DATA USE |
|--|---------------------------------------|---|--|
| McArthur and Miller (1989) | Pu, Cs, Th, U, K | Collect data to help estimate population doses of radiation from fallout originating at the Nevada Test Site (NTS) | Interpretation of BSCP soil data against regional values |
| Lawton (1989) | Pu | Determine background levels, satisfy requirements for RFP ER Program for background characterization | Interpretation of BSCP soil data against regional values |
| Purtymun et al. (1990) | Pu | Examine variations in Pu concentrations and ratios resulting from fallout in soils and in river and reservoir sediments in northern New Mexico and southern Colorado | Interpretation of BSCP soil data against regional values |
| Western Technologies, Inc. (1991) | Pu | Ensure public, worker and customer safety by analyzing surface soils on land located on the RFP west buffer zone where future sand and gravel mining is proposed | Used for exploratory data analysis |
| CDH - Terry (1991) | Pu, U, Cs | Support the existing body of conclusions that ^{239/240} Pu concentrations increase as the RFP site is approached, demonstrate that concentrations are changing over time, and fill in gaps in the body of data | Used for exploratory data analysis, Interpretation of BSCP soil data against regional values |
| Kabata-Pendias and Pendias (1992) | metals, trace elements | Synthesize global values from literature review | Interpretation of BSCP soil data against regional values |
| C.S.U. Radioecology Group (1993) | Pu, Am, Cs, Ra | Analyze levels from background plots predominantly upwind (west) of RFP | Interpretation of BSCP soil data against regional values |
| Litaor (1993b) | Pu | Geostatistical approach to a spatial analysis of Pu activity in the soils east of RFP | Used for exploratory data analysis |
| Litaor (1993a) | Pu | Using soil pits, assess the fate and transport of actinides in soil downwind of contaminated areas at RFP | Used for exploratory data analysis |
| OU1, OU2, OU3, OU5, OU6, OU7, Environmental Monitoring and Assessment Division, Project Task 6 | radionuclides, metals, semi-volatiles | Determine on-site contamination levels | Used for exploratory data analysis |

TABLE 3-2

REGIONAL CONCENTRATIONS OF RADIONUCLIDES IN SURFACE SOILS

| RANGE (pCi/g) | MEAN (pCi/g) | REFERENCE | NOTES |
|-------------------------|-----------------|-----------------------------------|---|
| ¹³⁷Cs | | | |
| 0.2967 - 0.8 | 0.4997 | Hardy (1976) | 13 Utah sites, 1971, 30 cm depth |
| 0.48 - 1.53 | 0.7967 | Hardy (1976) | 18 sites (Nevada, Utah, Wyoming, Idaho), 1974, 15 cm depth |
| 0.09 - 2.26 | N/A | McArthur and Miller (1989) | 213 sites (17 states), 1983, 5 cm depth |
| 0.37 - 1.156 | N/A | McArthur and Miller (1989) | 9 Colorado western slope sites, 1983, 5 cm depth |
| 0.403 - 1.404 | N/A | Miller et al. (1980) | 28 sites in southern Nevada, 0-2.5 cm depth |
| <0.37 - 0.58 | N/A | CDH - Terry (1991) | Eight Colorado communities, 1989, 0-0.64 cm depth, 2 mm sieve |
| 0.0270 - 2.4865 | N/A | Kabata-Pendias and Pendias (1992) | Louisiana State, 15 cm depth |
| ²²⁶Ra | | | |
| 0.49 - 1.98 | 0.79 | Myrick et al. (1983) | World averages |
| 0.23 - 4.2 | 1.1 +/- 0.48 | Myrick et al. (1983) | United States (33 states), 327 samples, 6 cm depth |
| 0.48 - 3.4 | 1.4 +/- 1.1 | Myrick et al. (1983) | Colorado, 32 samples, 6 cm depth |
| | 0.79 | Myrick et al. (1983) | Soil |
| 50 - 1,000 | 280 | Eisenbud (1987) | Mill tailings pile |
| N/A | 1.3 | Eisenbud (1987) | Igneous rock |
| N/A | 0.71 | Eisenbud (1987) | Sedimentary sandstones |
| N/A | 1.08 | Eisenbud (1987) | Sedimentary shales |

TABLE 3-2 (CONTINUED)

REGIONAL CONCENTRATIONS OF RADIONUCLIDES IN SURFACE SOILS

| RANGE (pCi/g) | MEAN (pCi/g) | REFERENCE | NOTES |
|--|-----------------|-------------------------|---|
| ²²⁶Ra (Concluded) | | | |
| N/A | 0.42 | Eisenbud (1987) | Limestones |
| N/A | 0.73 | Eisenbud (1987) | Soils |
| ²²⁸Ra | | | |
| Approximately 1:1 ratio to ²²⁶ Ra in soil and water | N/A | Eisenbud (1987) | |
| ²³²Th | | | |
| 0.22 - 1.31 | 0.65 | Myrick et al. (1983) | World averages |
| 0.10 - 3.4 | 0.98 +/- 0.46 | Myrick et al. (1983) | United States, 331 samples, 6 cm depth |
| 0.10 - 3.1 | 1.3 +/- 1.4 | Myrick et al. (1983) | Colorado, 20 samples, 6 cm depth |
| ²³⁸U | | | |
| 0.33 - 1.32 | 0.66 | Myrick et al. (1983) | World averages outside of the U.S. |
| 0.12 - 3.8 | 1.0 | Myrick et al. (1983) | United States, 0-6 cm depth |
| 0.47 - 3.0 | 1.2 | Myrick et al. (1983) | Colorado, 0-6 cm depth |
| ²⁴¹Am | | | |
| 0.014 - 0.216 | N/A | Poet and Martell (1972) | 5 sites within 10 miles of RFP, sieved 0.05 cm diameter, 0-1 cm depth |

TABLE 3-2 (CONCLUDED)

REGIONAL CONCENTRATIONS OF RADIONUCLIDES IN SURFACE SOILS

| RANGE (pCi/g) | MEAN (pCi/g) | REFERENCE | NOTES |
|------------------|-----------------|-------------------------|---|
| ⁹⁰ Sr | | | |
| 0.450 - 2.311 | N/A | Poet and Martell (1972) | Colorado Eastern Slope areas, 0-1 cm depth |
| 0.153 - 0.563 | N/A | Poet and Martell (1972) | Denver area sites at distances greater than 10 miles from RFP, 0-1 cm depth |
| 0.131 - 2.514 | N/A | Poet and Martell (1972) | Within 10 miles of RFP, 0-1 cm depth |

NOTE: All data reported in pCi/g.

TABLE 3-3

SUMMARY OF RADIONUCLIDES IN SURFACE SOILS AT RFP

| RADIONUCLIDE | RANGE OF VALUES (pCi/g) | NUMBER OF SAMPLES | MEAN (pCi/g) | MEDIAN (pCi/g) |
|----------------------|----------------------------|----------------------|-----------------|-------------------|
| ²⁴¹ Am | -0.190 - 163.467 | 576 | 1.624 | 0.022 |
| ¹³⁷ Cs | -0.072 - 2.500 | 253 | 0.465 | 0.258 |
| ^{89/90} Sr | 0.015 - 2.870 | 218 | 0.317 | 0.182 |
| ^{233/234} U | 0.218 - 2800.00 | 609 | 6.143 | 0.982 |
| ²³⁵ U | -0.015 - 670.00 | 609 | 1.266 | 0.044 |
| ²³⁸ U | 0.283 - 38000.00 | 609 | 68.520 | 1.017 |

Note: Pu not included.

Pu is the focus of the following discussion because it is a contaminant of concern at RFP and is an indicator of a group of radionuclides present in soils due to fallout. A summary of the ranges of $^{239/240}\text{Pu}$ concentrations, as determined from regional studies [i.e., not within 6.2 km (10 mi) of RFP] is presented in Table 3-4. The variability of the $^{239/240}\text{Pu}$ concentrations from these studies is illustrated in Figure 3-1.

Significant variability in the distribution of anthropogenic radionuclide concentrations is found in the environment. This variability has been attributed to regional and local meteorological conditions and topographical features of the earth's surface (Perkins and Thomas, 1980, and Purtyman, et. al., 1990). Perkins and Thomas (1980) indicated that weather patterns may influence the movement, dispersion, and ultimate deposition of radioactive debris. Uneven distribution of fallout on the earth's surface also can be caused by rain and snow scavenging of radioactive particles. Topography affects the deposition of fallout. Perkins and Thomas (1980) have shown that as air masses move west to east across the United States and are orographically lifted over mountain ranges, the fallout radionuclide concentration deposited on the ground may increase on the downwind side due to the downwind mixing of high-level air containing elevated concentrations of both airborne anthropogenic and cosmogenic radionuclides. Measurements on the downwind sides of both the Cascade Mountain Range and the Rocky Mountains have demonstrated this effect (Perkins and Thomas, 1980).

Site-specific sources of radioactive contamination from the Pu processing plant at RFP have been identified; Krey and Hardy (1970) listed four probable sources for off-site contamination:

- Fire in Building 771 on September 11, 1957
- Fire in Building 776 on May 11, 1969
- Chronic low-level stack emissions
- Resuspension of contaminated soil from leaking drums at the 903 Pad.

Pu data for soils in the plant vicinity showed the presence of Pu, but not in the distribution consistent with meteorological conditions at the time of the fires (Eisenbud, 1987). The Krey and Hardy investigation concluded "that the 903 Pad was the primary source of off-site soil Pu contamination from the Rocky Flats Plant" (DOE, 1991). A summary of the ranges in $^{239/240}\text{Pu}$ concentrations, from studies conducted at RFP and in the RFP vicinity, is presented in Table 3-5.

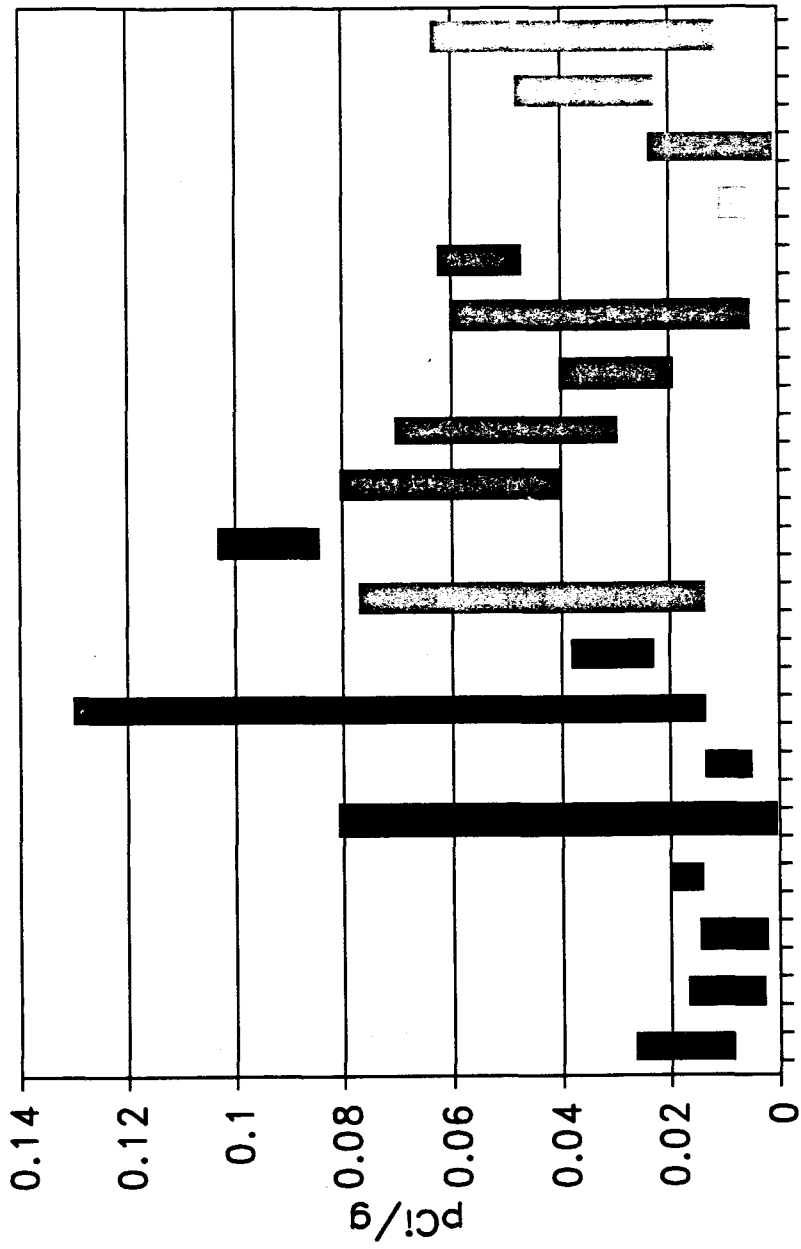
TABLE 3-4

REGIONAL $^{239/240}\text{Pu}$ CONCENTRATIONS IN SURFACE SOILS

| RANGE (pCi/g) | REFERENCE | NOTES |
|------------------|--|---|
| 0.006 - 0.01 | Krey and Hardy (1970) | More than 10 miles from RFP, 0-20 cm depth, assumed soil density of 1.5 g/cm ³ for range calculation |
| 0.023 - 0.048 | Poet and Martell (1972) | Colorado eastern slope area, 0-1 cm depth |
| 0.012 - 0.063 | Poet and Martell (1972) | Denver area, 0-1 cm depth, 1970 |
| 0.048 - 0.062 | Geographic Effects and Texture of the Fallout Blanket - Michels | Range of averages from cross-sections, Great Plains, 1972, assumed 5 cm depth and a soil density of 1.5 g/cm ³ for range calculation |
| 0.0051 - 0.0133 | Hardy (1976) | 13 Utah sites, 1971, 0-30 cm depth, assumed soil density of 1.5 g/cm ³ for range calculation |
| 0.014 - 0.13 | Hardy (1976) | 18 sites (Nevada, Utah, Wyoming, Idaho), 1974, 0-15 cm depth, soil density of 1 g/cm ³ for range calculation |
| 0.0011 - 0.0238 | ORNL - Holleman et al. (1987) | Denver, Colorado, 1965-1970, assumed 0-5 cm depth and soil density of 1 g/cm ³ for range calculation |
| 0.006 - 0.324 | McArthur and Miller (1989) | 171 sites (17 states), 0-5 cm depth, assumed soil density of 1 g/cm ³ for range calculation |
| 0.024 - 0.038 | McArthur and Miller (1989) | 6 Colorado western slope sites, 0-5 cm depth, assumed soil density of 1 g/cm ³ for range calculation |
| 0.014 - 0.077 | Lawton (1989) | 8 communities in eastern half of Colorado, 0-5 cm depth |
| 0.0088 - 0.0264 | Purtymun et al. (1990) | Santa Cruz Lake, 1984, 0-5 cm depth |
| 0.0028 - 0.0178 | Purtymun et al. (1990) | 50-mile radius of Los Alamos, 1981, 0-5 cm depth |

TABLE 3-4 (CONCLUDED)
REGIONAL $^{239,240}\text{Pu}$ CONCENTRATIONS IN SURFACE SOILS

| RANGE (pCi/g) | REFERENCE | NOTES |
|--------------------------|------------------------|--|
| 0.0027 - 0.0156 | Purtymun et al. (1990) | 50-mile radius of Los Alamos, 1983, 0-5 cm depth |
| 0.015 - 0.020 | Purtymun et al. (1990) | Soil surface layer midwest |
| Upper limit = 0.030 | Purtymun et al. (1990) | Soils in northern New Mexico, 0-5 cm depth, 1974-1986 |
| 0.0012 - 0.081 | Purtymun et al. (1990) | Soils in northern New Mexico and southern Colorado, 1981, 1983, 1986, 0-5 cm depth |
| 0. - 0.06 | CDH - Terry (1991) | Eight Colorado communities, 0-0.64 cm depth, 2 mm sieve |



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FIGURE 3-1
 VARIABILITY OF $^{239/240}\text{Pu}$
 IN SURFACE SOILS -
 LITERATURE VALUES

TABLE 3-5

239/240Pu CONCENTRATIONS SURFACE SOILS AT RFP

| RANGE (pCi/g) | REFERENCE | NOTES |
|------------------|-----------------------------------|---|
| 0.086 - 0.103 | CSU Radioecology Group (1993) | West of RFP, 0-3 cm depth, 0-45 μ m portion |
| 0.04 - 0.08 | CDH - Terry (1991) | Sector 5 (NW), 0-0.64 cm depth, 2 mm sieve, 1975-1989 |
| 0.03 - 0.07 | CDH - Terry (1991) | Sector 8 (SW), 0-0.64 cm depth, 2 mm sieve, 1975-1989 |
| 0.02 - 0.04 | CDH - Terry (1991) | Sector 12 (NE), 0-0.64 cm depth, 2 mm sieve, 1975-1989 |
| 0.005 - 0.06 | CDH - Terry (1991) | Sector 13 (NW), 0-0.64 cm depth, 2 mm sieve, 1970-1989 |
| 0.0078 - 6.5 | Krey and Hardy (1970) | Within 10 miles of RFP, 0-20 cm depth, assumed soil density of 1.5 g/cm ³ for range calculation |
| 0.015 - 6.08 | Poet and Martell (1972) | Near RFP, 1969-1970, 0-1 cm depth |
| 0.27 - 59.4 | Loser and Tibbals (1972) | East of Indiana Avenue, 1969-1972 |
| 0.009 - 3.423 | Illsley and Hume (1979) | 151 locations in private lands along the west, south, and east plant boundaries, sieved through 10 mesh screen, 0-5 cm depth |
| 0.0 - 0.695 | Western Technologies, Inc. (1991) | 54 sites within 478 acres on RFP west buffer zone, 1990, 0-0.64 cm depth |
| 0.006 - 3000. | Combined OU Studies | Combined OUs 1, 2, 3, 5, 6, 7, Illsley's lawsuit, Environmental Monitoring and Assessment Division, Project Task 6 Studies and Annual Soil Monitoring Reports, 0-5 cm depth |

The Rock Creek drainage background study is of particular interest to the BSCP. Samples from 18 locations in the Rock Creek drainage (the Rock Creek data set) in the northwest quadrant of the buffer zone of the RFP were collected in 1992 and 1993. Those data were collected in support of RCRA/CERCLA investigations for OU1 and OU2 to establish a background soil chemistry for determining the nature and extent of contamination, and for human health risk-assessment purposes. The sample locations were selected to represent soil types found in OU1 and OU2, but upwind and upgradient of suspected contaminant sources. Samples were analyzed for ^{241}Am , gross alpha particle activity, gross beta particle activity, $^{239/240}\text{Pu}$, $^{226/228}\text{Ra}$, and $^{233/234/235/238}\text{U}$. Table 3-6 provides the radionuclide measurements for the Rock Creek drainage study.

3.2 METALS

This section summarizes pertinent information regarding background concentrations of metals in soils. The concept of natural variability of metals in soils is important with respect to background concentrations. Soil minerals are products of a complex chain of events involving the action of weathering, topography, and biota on the parent geologic material. Because background metals concentrations in soil are substantively influenced by geologic parent material, geomorphic processes, degree of weathering, and other site-specific factors, metals concentrations are expected to exhibit a high degree of variability when evaluated over a broad region.

Based on an analysis of data presented in six references, Dragun (1988) has compiled typical ranges and observed extreme limits of background concentrations for elements in natural soil (Table 3-7). These values were obtained from a variety of soils and soil depths. Kabata-Pendias and Pendias (1992) have listed ranges and means of total concentrations of trace elements in surface soils calculated on the world scale as they occur in different soils (Table 3-7). Schacklette and Boerngen (1984) present concentration means and observed ranges for the conterminous United States and for the eastern (east of the 96th meridian) and western (west of the 96th meridian) United States subgroups. Metals concentration ranges for the western subgroup are included in Table 3-7.

Site-specific data regarding metals for most of the OU studies and the Rock Creek data set are also available for comparison. Table 3-8 presents the concentration ranges from the combined OU1, OU2, OU3, OU5, OU6, OU7, the former RFP Environmental Monitoring and Assessment Division (EMAD) and Rock Creek drainage sampling results. Table 3-9 presents the results for the Rock Creek data set.

TABLE 3-6
RADIONUCLIDES IN SURFACE SOILS FROM ROCK CREEK STUDY (pCi/g)

| ANALYTE | MEAN | STANDARD DEVIATION | NUMBER OF SAMPLES | CALCULATED TOLERANCE FACTOR | UPPER 99% TOLERANCE LEVEL AT 99% CONFIDENCE |
|-------------------|-------------|-------------------------------|------------------------------|--|--|
| Americium-241 | 0.01854 | 0.00920 | 15 | 4.2224 | 0.06 |
| Cesium-137 | 1.41 | 0.48970 | 12 | 4.6330 | 3.68 |
| Gross alpha | 19.825 | 4.91600 | 10 | 5.0737 | 44.77 |
| Gross beta | 32.031 | 5.69900 | 19 | 3.8924 | 54.21 |
| Plutonium-239,240 | 0.05523 | 0.02023 | 18 | 3.9604 | 0.14 |
| Radium-226 | 0.94538 | 0.12813 | 10 | 5.0737 | 1.60 |
| Radium-228 | 2.1767 | 0.53090 | 10 | 5.0737 | 4.87 |
| Strontium-89,90 | 0.61833 | 0.29768 | 9 | 5.3889 | 2.22 |
| Uranium-233,234 | 1.14497 | 0.15557 | 16 | 4.1233 | 1.79 |
| Uranium-235 | 0.05263 | 0.03271 | 16 | 4.1233 | 0.19 |
| Uranium-238 | 1.18301 | 0.18799 | 16 | 4.1233 | 1.96 |

TABLE 3-7

REGIONAL METAL CONCENTRATIONS IN SURFACE SOILS

| ANALYTE | DRAGUN (1988) | | KABATA-PENDIAS AND PENDIAS (1992) | | | | SHACKLETTE AND BOERNGEN (1984) | |
|---------|---------------|--------------|-----------------------------------|------|-----------------------|------|---|-------|
| | TYPICAL | EXTREME | SANDY SOIL | | SILTY AND LOAMY SOILS | | WESTERN UNITED STATES (WEST OF 96TH MERIDIAN) | |
| | | | | | | | | |
| | RANGE | LIMITS | RANGE | MEAN | RANGE | MEAN | RANGE | MEAN |
| As | 1.0 - 4.0 | 0.1 - 500 | <0.1 - 30 | 4.4 | 1.3 - 27 | 8.4 | <0.1 - 97 | 7.00 |
| Be | 0.1 - 40 | 0.1 - 100 | N/A | N/A | N/A | N/A | <1 - 15 | 0.97 |
| Cd | 0.01 - 7.0 | 0.01 - 45 | 0.1 - 2.7 | 0.37 | 0.08 - 1.61 | 0.45 | N/A | N/A |
| Cr | 5.0 - 3,000 | 0.5 - 10,000 | 1.4 - 530 | 47 | 4 - 1,100 | 51 | 3 - 2,000 | 56 |
| Hg | 0.01 - 0.08 | N/A | 0.008 - 0.7 | 0.05 | 0.01 - 1.1 | 0.1 | <0.01 - 4.6 | 0.065 |
| Li | 7.0 - 200 | 1.0 - 3,000 | <5 - 72 | 22 | 1.4 - 130 | 46 | 5 - 130 | 24 |
| Ni | 5.0 - 1,000 | 0.8 - 6,200 | 1 - 110 | 13 | 3 - 110 | 26 | <5 - 700 | 19 |
| Pb | 2.0 - 200 | 0.1 - 3,000 | 2.3 - 70 | 22 | 1.5 - 70 | 28 | <10 - 700 | 20 |
| Se | 0.1 - 2.0 | 0.01 - 400 | 0.005 - 1.32 | 0.25 | 0.02 - 1.9 | 0.34 | <0.1 - 4.3 | 0.34 |

NOTE: All concentrations are ppm.

N/A - Not Available

TABLE 3-8**METALS CONCENTRATIONS IN SURFACE SOILS AT RFP**

| ANALYTE | RANGE | NUMBER OF SAMPLES | MEAN | MEDIAN |
|----------------|---------------|------------------------------|-------------|---------------|
| As | 0.21 - 19.90 | 694 | 4.96 | 4.80 |
| Be | 0.06 - 6.20 | 694 | 0.81 | 0.78 |
| Ca | 0.43 - 6.40 | 425 | 0.91 | 0.87 |
| Cr | 0.94 - 85.30 | 428 | 12.47 | 11.95 |
| Hg | 0.03 - 0.38 | 414 | 0.10 | 0.10 |
| Pb | 1.70 - 145.00 | 405 | 26.85 | 23.30 |
| Li | 1.90 - 22.90 | 356 | 8.59 | 8.10 |
| Ni | 2.40 - 54.30 | 372 | 12.35 | 11.84 |
| Se | 0.20 - 1.63 | 454 | 0.41 | 0.37 |

NOTE: Data reported in ppm.

TABLE 3-9

**METALS CONCENTRATIONS IN SURFACE SOILS FROM ROCK CREEK STUDY
(mg/kg)**

| ANALYTE | MEAN | STANDARD DEVIATION | UPPER 99% TOLERANCE LIMIT AT 99% CONFIDENCE |
|----------------|-------------|-------------------------------|--|
| Aluminum | 12,992.9 | 2,251.53 | 21,909.86 |
| Antimony | 10.525 | 1.724 | 17.35 |
| Arsenic | 5.817 | 1.818 | 13.02 |
| Barium | 195.2 | 84.63 | 530.37 |
| Beryllium | 0.9983 | 0.256 | 2.00 |
| Cadmium | 1.048 | 0.362 | 2.51 |
| Calcium | 5,068.1 | 2,220.5 | 13,862.17 |
| Cesium | 61.43 | 61.43 | 304.72 |
| Chromium | 15.207 | 2.798 | 26.10 |
| Cobalt | 7.781 | 4.305 | 24.83 |
| Copper | 12.964 | 3.629 | 27.34 |
| Iron | 15,381.7 | 3,226.62 | 28,160.41 |
| Lead | 37.535 | 6.024 | 61.39 |
| Lithium | 10.98 | 2.273 | 19.98 |
| Magnesium | 2,853.3 | 1,049.95 | 7,011.52 |
| Manganese | 443.67 | 457.01 | 2,253.61 |
| Mercury | 0.09256 | 0.0306 | 0.21 |
| Molybdenum | 3.31997 | 1,59652 | 9.64 |
| Nickel | 12.578 | 3.588 | 26.79 |
| Potassium | 2,977.9 | 575.47 | 5,256.99 |
| Selenium | 0.4785 | 0.1468 | 1.06 |
| Silicon | 780.99 | 700.452 | 3,555.06 |
| Silver | 1.728 | 0.693 | 4.47 |

TABLE 3-9 (CONCLUDED)

**METALS CONCENTRATIONS IN SURFACE SOILS FROM ROCK CREEK STUDY
(mg/kg)**

| ANALYTE | MEAN | STANDARD DEVIATION | UPPER 99% TOLERANCE LIMIT AT 99% CONFIDENCE |
|----------------|-------------|-------------------------------|--|
| Sodium | 175.14 | 75.031 | 472.29 |
| Strontium | 35.331 | 13.811 | 90.03 |
| Thallium | 0.3773 | 0.1204 | 0.85 |
| Tin | 38.346 | 9.2105 | 74.82 |
| Vanadium | 31.603 | 6.049 | 55.56 |
| Zinc | 55.824 | 7.795 | 86.70 |

NOTE: Number of samples = 18.
 Calculated Tolerance Factor = 3.9604

3.3 SEMIVOLATILE ORGANICS

Studies describing the occurrence of organic compounds in background soils were reviewed to provide insight into both natural and anthropogenic sources to background concentrations. The emphasis of the literature search and review was on semivolatile organic compounds, such as polynuclear aromatic hydrocarbons (PAHs). PAH concentrations, as well as pesticides and herbicides, are highly dependent on land use in the area where samples are collected. Input to the background environment via vehicle exhaust is probably the most prevalent anthropogenic source for PAHs, thus samples collected in industrial areas or near roadways may exhibit elevated concentrations with respect to isolated areas. Naturally-occurring organic chemicals are present on the EPA Target Compound List (TCL) and are summarized on Table 3-10 (Dragun, 1988).

Semivolatile organic, pesticide, and polychlorinated biphenyls (PCBs) have been collected for most of the OU studies ongoing at RFP and also for the Rock Creek drainage background study. Herbicides have also been collected for the OU studies. The purpose of evaluating the studies with respect to the organic analyte suite was to examine background concentration ranges for future RCRA/CERCLA decision-making.

Table 3-11 lists the organic compounds and the corresponding concentration ranges from the combined OU1, OU2, OU3, OU5, OU6, OU7, EMAD, and Rock Creek drainage sampling results. Herbicides have also been collected for the OU studies. The tabulated values are not to be construed as contaminant ranges (i.e. background comparisons were not performed as part of work plan preparation). For the Rock Creek drainage background study, the only semivolatile organic compounds detected were benzoic acid (43 to 230 ppm), bis(2-ethylhexyl)phthalate (35 to 140 ppm), and di-n-octylphthalate (39 to 44 ppm), and are considered estimates because the concentrations observed were below the reported quantitation limit.

3.4 SOIL PROFILE DATA

Twenty-six soil pits at various distances and directions downwind (i.e. east) of the 903 Pad were excavated, sampled, and analyzed for actinide activities, as well as for selected physical, chemical, and mineralogical attributes (Litaor, 1993a). The backhoe excavated soil pits were dug to a depth of 1.0 m (3.3 ft). Locations of the soil pits were chosen to represent the major soil types at RFP. The soils were classified according to the USDA-SCS soil classification scheme. Actinide activities and physiochemical parameters suspected of affecting actinide activities in soil were studied to assess the fate and transport of actinides in soil downwind of

TABLE 3-10

SUMMARY OF SEMIVOLATILE ORGANIC CONSTITUENT CONCENTRATIONS
IN SURFACE SOILS (ppb)

| ANALYTE | DRAGUN (1988) |
|----------------------------|-------------------|
| Benz(a)anthracene | 0 - 10 |
| Benzo(b)fluoranthene | 0 - 30 |
| Benzo(k)fluoranthene | 0 - 15 |
| Benzoic acid | 140 - 11,000 |
| Benzo(g,h,)perylene | 0 - 20 |
| Benzo(a)pyrene | 0 - 8,000 |
| bis(2-ethylhexyl)phthalate | 150,000 - 925,000 |
| Chrysene | 5,000 |
| Dibutylphthalate | 19,000 - 56,000 |
| Diethylphthalate | 0 - 13,000 |
| Fluoranthene | 0 - 40 |
| Ideno(1,2,3-cd)pyrene | 0 - 15 |
| Naphthalene | 1,000 - 5,000 |
| Pyrene | 0 - 15 |

TABLE 3-11

SITE-SPECIFIC ORGANIC COMPOUNDS DETECTED IN SURFACE SOILS

| COMPOUND | CONCENTRATION RANGE ($\mu\text{g/kg}$) | NUMBER OF SAMPLES WITH DETECTED CONCENTRATIONS |
|----------------------------|---|---|
| 2,4-Dichlorophenol | 790 - 1,200 | 4 |
| 2-Methylnaphthalene | 73 - 1,200 | 8 |
| 4-Methylphenol | 270 | 2 |
| 4-Nitrophenol | 53 | 1 |
| Acenaphthene | 39 - 4,600 | 62 |
| Acenaphthylene | 38 - 600 | 3 |
| Anthracene | 44 - 5,500 | 68 |
| Benzo(a)anthracene | 38 - 8,300 | 162 |
| Benzo(a)pyrene | 36 - 11,000 | 137 |
| Benzo(b)fluoranthene | 32 - 11,000 | 139 |
| Benzo(g,h,i)perylene | 15 - 6,900 | 95 |
| Benzo(k)fluoranthene | 32 - 8,500 | 111 |
| Benzoic Acid | 43 - 97,000 | 72 |
| Benzyl Alcohol | 270 | 1 |
| Bis(2-ethylhexyl)phthalate | 35 - 25,000,000 | 122 |
| Butyl Benzyl Phthalate | 45 - 380 | 15 |
| Chrysene | 36 - 11,000 | 175 |
| Di-n-Butyl Phthalate | 36 - 42,000 | 66 |
| Di-n-octyl Phthalate | 39 - 1,300 | 18 |
| Dibenzo(a,h)anthracene | 37 - 7,000 | 38 |
| Dibenzofuran | 36 - 2,000 | 25 |
| Diethyl Phthalate | 1,100 - 16,000 | 2 |
| Dimethyl Phthalate | 89 - 94 | 2 |
| Fluoranthene | 42 - 18,000 | 210 |

TABLE 3-11 (CONCLUDED)

SITE-SPECIFIC ORGANIC COMPOUNDS DETECTED IN SURFACE SOILS

| COMPOUND | CONCENTRATION RANGE ($\mu\text{g/kg}$) | NUMBER OF SAMPLES WITH DETECTED CONCENTRATIONS |
|--------------------------------|---|---|
| Fluorene | 37 - 3,300 | 54 |
| Indenol(1,2,3-cd)pyrene | 39 - 7,300 | 110 |
| Isophorone | 96 | 1 |
| Naphthalene | 37 - 3,000 | 24 |
| Pentachlorophenol | 2,200 - 2,400 | 2 |
| Phenanthrene | 37 - 22,000 | 181 |
| Pyrene | 41 - 16,000 | 210 |
| Aldrin | 17 - 67 | 4 |
| Aroclor-1242 | 41 - 25,000 | 12 |
| Aroclor-1248 | 52 - 230,000 | 37 |
| Aroclor-1254 | 9.7 - 860,000 | 126 |
| Aroclor-1260 | 9.6 - 680,000 | 240 |
| 4,4'-DDD | 22 | 1 |
| 4,4'-DDT | 21 - 26 | 2 |
| Delta-BHC | 23 | 1 |
| Dieldrin | 18 - 53 | 4 |
| Endosulfan Sulfate | 24 | 1 |
| Endrin Ketone | 36 | 1 |
| Heptachlor Epoxide | 10 | 1 |
| Methoxychlor | 450 | 1 |
| Propane, 1,1-dibromo-3-chloro- | 54 - 89 | 11 |

contaminated areas at RFP. Litaor (1993a) indicated that pedogenic factors, especially biological activity (notably earthworm activity), are important factors in the fate and transport of actinides in the soil environment. However, the results of the study strongly suggested that the actinides in the soils around RFP are relatively immobile. Downward movement of actinides located downwind of the contaminated areas was largely restricted to the upper 12 cm (4.72 in) of soil. The soil profile sampling for the BSCP has been designed to support fate and transport studies by collecting baseline soils data from representative soils in areas upwind of contaminated areas.

3.5 SURFACE SOIL SAMPLING METHODOLOGIES

Except for the soil profile studies mentioned in Section 3.4, most soil sampling methods at RFP have focused investigations in the upper several cm of soil. Various surface soil sampling methods have been used at RFP since 1969 primarily for two purposes; assessing potential health hazards and determining contaminant concentrations. For Pu in particular, sampling methods have been used to assess risk to human health from Pu through the inhalation pathway and to determine Pu inventories in the soil. Comparability between historic surface soil data may be dependant on the sampling method used and the time between sampling periods. Typically, the methods for determining the Pu inventory in the soil involve sampling to depths ranging from zero to five cm (two in) or to 20 or 30 cm (7.9 or 11.8 in), while the methods for assessing health risk through the inhalation pathway involve depths from zero to five cm (zero to two in). Table 3-5 lists the depths for several historical investigations regarding RFP-related activities and regional studies.

Two surface soil sampling methods have been used since 1990 at RFP for RCRA/CERCLA-related activities. They are the CDH method and the Rocky Flats (RF) method, both of which are outlined in EG&G Operating Procedure GT.8. The CDH method obtains a composite sample from 25 subsample locations within a 1.6- or a 4.0-ha (4- or a 10-acre) plot size. Each subsample is obtained by removing the soil from a 5.1 cm (two in) by six cm (2.4 in) by 0.64 cm (0.25 in) deep template driven into the soil. The RF method obtains a composite sample from 10 subsample locations within two one-meter (3.3-ft) square (m²) areas; each subsample obtained by removing soil from a 10 cm (3.9 in) by 10 cm (3.9 in) by five cm (two in) deep template which is driven into the soil.

As discussed further in Section 4.3.1, the RF method [five cm (two in) depth] was chosen for the BSCP over the CDH method [0.64 cm (0.25 in) depth] and other surface soil methods for the following reasons.

- The RF method is comparable to other RFP data collection efforts regarding risk assessment and determination of the nature and extent of contamination.
- The RF method has been used for ongoing environmental monitoring.
- The RF method is comparable to regional and worldwide sampling efforts which were designed to determine fallout radionuclide concentrations in soils.
- The RF method was developed for the rocky surface soils in the vicinity of RFP.
- The RF method is considered a compromise between determining total Pu inventories in the soil and providing information for assessing human health risk through the inhalation pathway.
- The Rock Creek data set utilized the RF method. Because the BSCP sampling effort is intended to augment the Rock Creek data set for certain analyte groups, the RF method is appropriate.
- Data collected by both the RF and CDH methods for OU3 Pu concentrations are comparable.

Section 4.3.1 further discusses data comparability among surface soil sampling methods.

4.0 DATA QUALITY OBJECTIVES

The purpose of this section is to establish and implement the DQO process for this project. This is accomplished through integration of EPA's DQO guidance and independent data evaluation methodologies using results of previous investigations (Section 3.0) to provide a technically defensible framework for design of a field sampling program (Section 5.0) and data analysis program (Section 6.0).

The work plan for the RFP BSCP is built upon the framework of the DQO process. The DQO process is a systematic planning tool based on the scientific method for identifying the type, quantity, and quality of data that will be appropriate for the intended application of the data. The goal of the process is to collect data of sufficient quantity and quality to support defensible decision making, while attempting to minimize expenditures related to data collection by eliminating unnecessary or overly precise data. The process allows the decision makers to define their data requirements and the acceptable levels of decision errors during planning, before data collection begins.

DQOs for the BSCP have been developed using the seven-step problem solving procedures outlined in the Guidance for Planning for Data Collection in Support of Environmental Decision Making Using the Data Quality Objective Process, (EPA, 1994) (Figure 4-1). However, to ensure comparability with previous RCRA/CERCLA OU investigations at RFP and to transition between the 1994 guidelines and previous EPA DQO guidelines, the format for the BSCP DQO section follows the three-stage DQO process outlined in the DQOs for remedial response activities (EPA, 1987a) (Figure 4-2).

Although the DQO Process is meant to be followed in a sequential manner, it is also iterative; the outputs from one step may influence prior steps and cause them to be redefined. As a result of this iterative process, it was recognized that groups of analytes (i.e., data types) had differing data needs to adequately characterize background concentrations. By approaching the evaluation of existing data and the sampling plan design on a data-type-specific basis, the designs became more manageable and representative of the actual data needs. Thus, the rationale applied to design the BSCP sampling plan evolved into a data-type-specific process (Figure 4-3). As indicated on Figure 4-3, the following data types were evaluated individually:

7 STEP DQO PROCESS

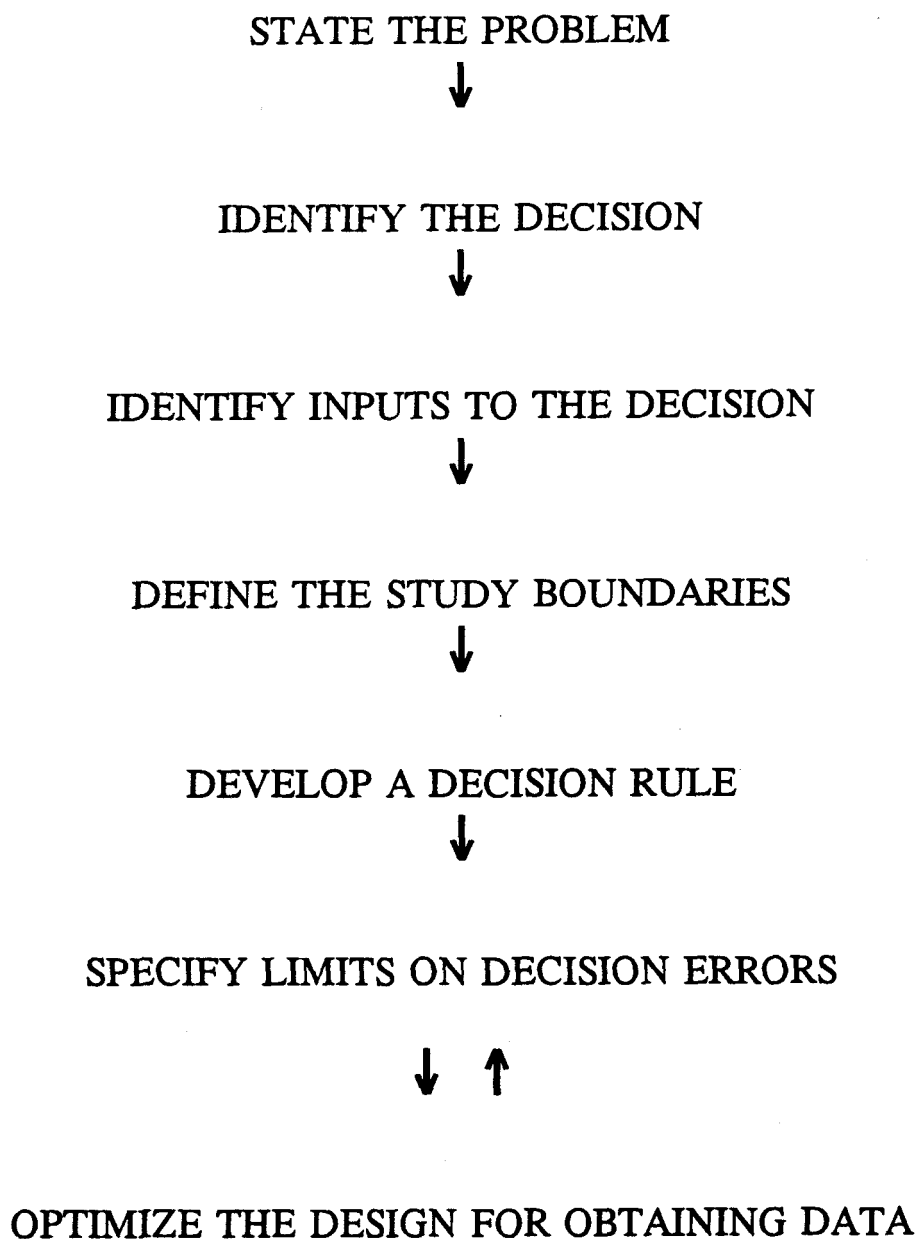


Figure 4-1 Seven-Step DQO process (EPA, 1994)

THREE-STAGE DQO PROCESS

STAGE 1 IDENTIFY DECISION TYPES

- Identify & Involve Data Users
- Evaluate Available Data
- Develop Conceptual Model
- Specify Objectives/Decisions



STAGE 2 IDENTIFY DATA USES/NEEDS

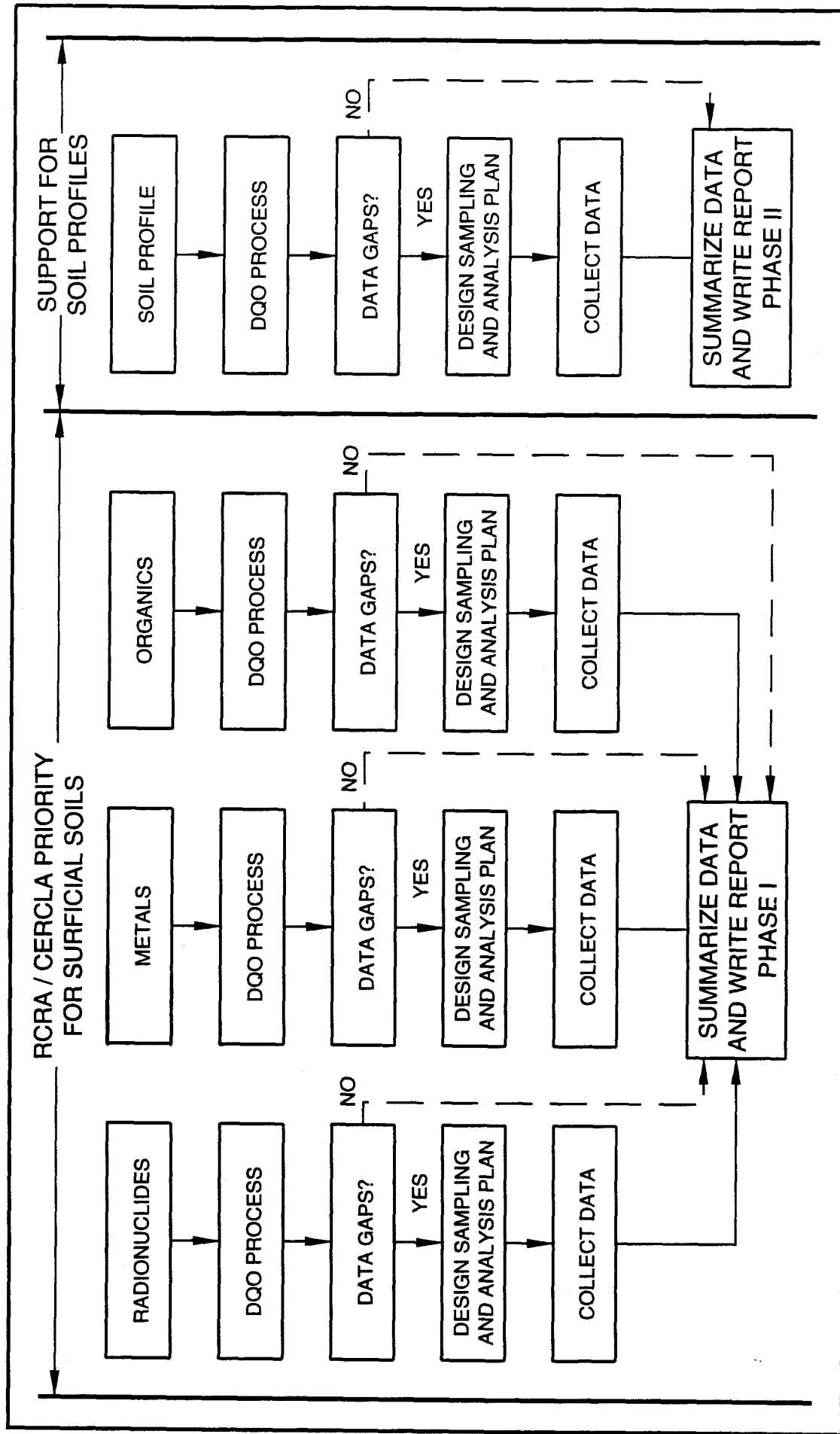
- Identify Data Uses
- Identify Data Types
- Identify Data Quality Needs
- Identify Data Quantity Needs
- Evaluate Sampling/Analysis Options
- Review PARCC Parameters



STAGE 3 DESIGN DATA COLLECTION PROGRAM

- Assemble Data Collection Components
- Develop Data Collection Documentation

Figure 4-2 Three-Stage DQO process [after EPA (1987a) and EPA (1987b)]



- Pu and other radionuclides from anthropogenic fallout sources (Fallout Group)
- Metals, including naturally occurring U and Ra isotopes (Metals Group)
- Organic compounds (Organic Group)
- Physical, chemical, and mineralogical characterization of background soils (Soil Profile Group).

Section 4.2.2, Data Types, and Section 4.3.2, Design Approach, discuss the rationale for delineation of these groups.

The need to obtain background data for the upper five cm (two in) of soil for radionuclides, metals, and organics was identified as a high priority based on RCRA/CERCLA decision-making data needs. The soil profile data type, collected primarily from genetic soil horizons and depth intervals in the upper 1.2 m (four ft) of soil by a pit/trench technique, was identified as a secondary (i.e., lower priority) data need.

The following sections discuss stages one, two, and three of the DQO process. The three stage process includes: Stage 1 - Identification of Decision Types, Stage 2 - Identification of Data Uses/Needs, and Stage 3 - Design Data Collection Program.

4.1 STAGE 1 - IDENTIFICATION OF DECISION TYPES

The purpose of Stage 1 of the DQO process (Figure 4-2) is to identify the individuals responsible for decisions regarding use of background soils characterization data, to identify and involve data users, and to define the types of decisions that will be made by those using the data.

As part of work plan preparation, Stage 1 was accomplished through four tasks:

- Identification and involvement of data users
- Evaluation of available information
- Development of background conceptual site model
- Specification of study objectives.

4.1.1 Identification and Involvement of Data Users

A planning team was assembled for the BSCP which included personnel from DOE, EG&G, and its subcontractor, Dames & Moore, and represented a variety of technical disciplines and organizations responsible for the outcome of the project. The first objective for the planning team was to identify potential data users and solicit their involvement by circulating questionnaires and conducting interviews regarding potential background soils data needs.

Data users for ER-related (i.e., RCRA/CERCLA) investigations have been categorized as follows:

- Decision makers
- Primary data users
- Secondary data users
- Technical support/review groups.

The potential data users for this project are identified in the following paragraphs. Decision makers include Remediation Project Managers (OU managers) for each of the 16 designated OUs at RFP and other personnel from EG&G, DOE, EPA, and CDH who are involved in decision making through management and regulatory oversight. The decision maker's role includes assessing the nature of contamination (the contaminants of concern), assessing the risks to human health and the environment posed by the contaminants, delineating the extent of the contaminated areas, deciding on acceptable remediation levels, and choosing feasible alternatives for cleanup operations.

Primary data users are geoscientists, soil scientists, ecologists, statisticians, chemists, risk assessors, modelers, remedial design engineers and others on the staffs of EPA, DOE, CDH, EG&G, and subcontractors involved in the BSCP and ongoing ER activities at RFP. The primary data user's role is to provide technical information and guidance to the ER decision makers.

Secondary data users include those involved with scientific investigations that support ER activities (i.e., RCRA/CERCLA investigations) at RFP, other facilities, public involvement groups, ongoing and future soil monitoring programs, and land managers.

Support groups include personnel from EG&G and its subcontractors, DOE, EPA, and CDH who are involved with laboratory management, database management, QA, records control, and compliance monitoring. Review groups include subcontractors to DOE or EG&G involved with technical review of the BSCP.

EPA and CDH were included as data users in the DQO process and were briefed through a March 3, 1994 meeting. At this meeting, information regarding the preliminary DQOs and sampling design for the project were presented for discussion. CDH's and EPA's oral comments were noted at this meeting and given due consideration in preparation of this draft plan.

4.1.2 Evaluation of Available Information

The goal of evaluating previous investigations (Section 3.0) was to identify data gaps and to provide the basis for BSCP sampling designs. Chemical data (i.e., radionuclide, metal, and organic analytical data) from previous investigations in surface soils were compiled for use in identifying data gaps and designing the sampling program (Section 4.3) for characterization of the upper five cm (two in) of soil.

Identification of data gaps for the soil profile data type was independent of that for the surface soils chemical data. In general, the sampling design component for the soil profile data type is based on soil type and slope position. Thus, the design basis is dependent only on sample site selection.

4.1.3 Development of Background Conceptual Site Model

A preliminary background conceptual model was developed for addressing data needs and to illustrate the rationale for choosing the general locations for potential background soil areas. The conceptual model incorporates the following elements:

- Measurable analytes of concern that the soils may contain
- Sources, both RFP and off-site, of those analytes
- The pathways of analyte migration leading from sources to the background soils.

The basic elements of a conceptual model for RCRA/CERCLA work as proposed by the EPA include a source, pathway, and receptors for contaminants. These elements were used in developing this preliminary conceptual model, although the "receptors" of contaminants in this case are the background soils.

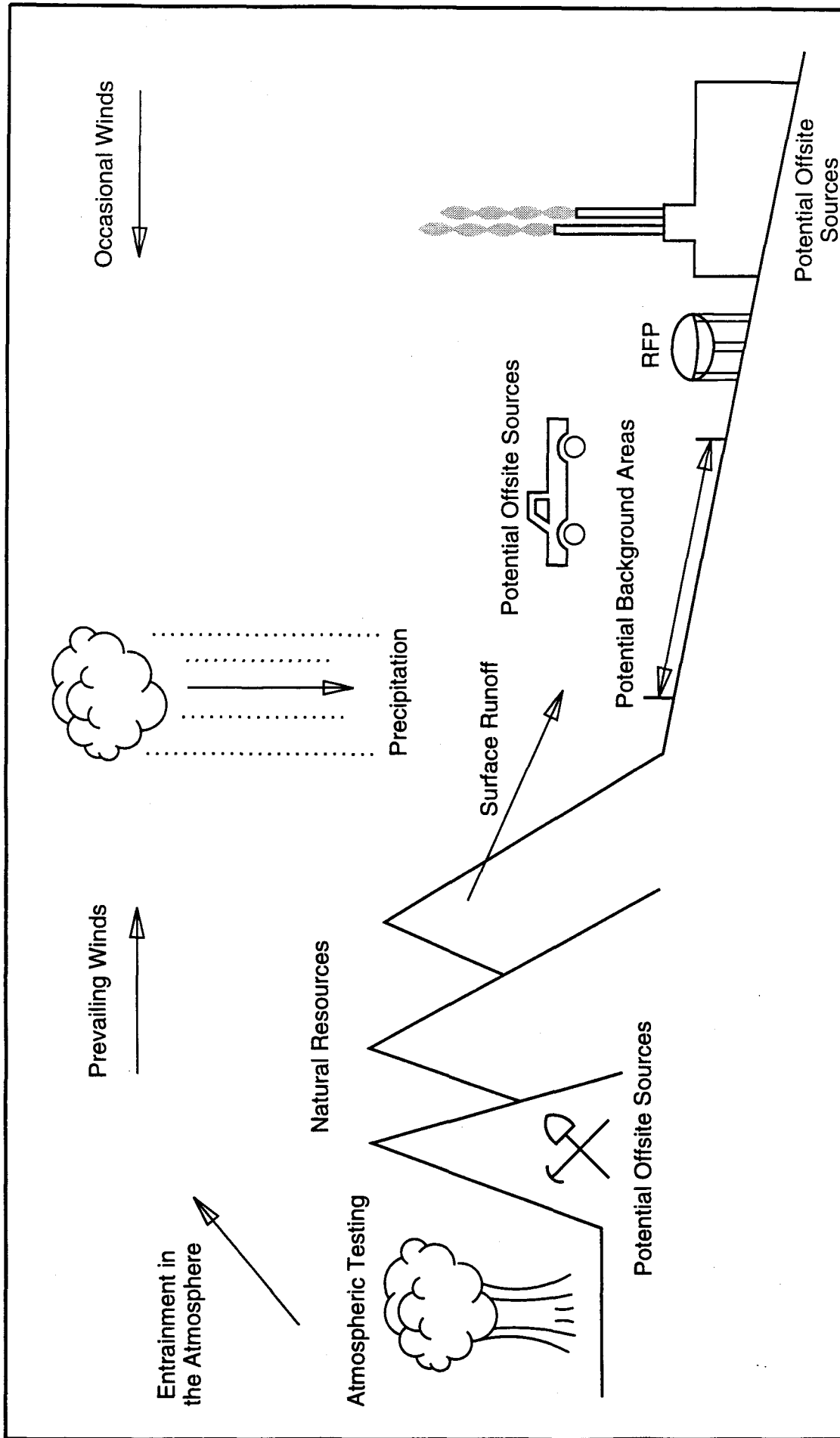
Off-site sources of contaminants include atmospheric testing of nuclear weapons, which was conducted in the northern hemisphere and produced radionuclides. Fallout radionuclides were entrained in the atmosphere, transported downwind by prevailing winds, and deposited on the surface soils via precipitation and dry deposition. A second, major off-site source of metals and radionuclides such as U and its daughter elements, are naturally occurring rocks, mineral deposits, and sediments. Background soils have developed from parent materials whose sources are from the mountains to the west of RFP, and from underlying sedimentary deposits. These parent materials may contribute naturally-occurring levels of potential analytes of concern to background soils. Transport of these potential analytes may have occurred through several mechanisms such as wind erosion, stream sediment transport, and transport of dissolved constituents via groundwater and surface water. Other potential sources of radionuclides, metals, and organic compounds are numerous off-site activities, which may generally be categorized as nonpoint source pollution. Activities capable of contributing contaminants to background soils in the RFP area include, but may not be limited to, industrial operations in the Denver metropolitan area, mining operations in the mountains, widespread agricultural chemical use, automobile and rail traffic in the vicinity, and small businesses/light industry in the immediate vicinity. A schematic representation of off-site sources of potential contaminants of concern and pathways leading to potential background soils areas is presented in Figure 4-4.

RFP also may have been a source for contributing contaminants to potential nearby background soil areas. A schematic representation of potential RFP sources and pathways is presented in Figure 4-5. RFP sources of contamination, associated pathways, and transport mechanisms (Figure 4-5) are considered when assessing potential areas for background soil sampling.

4.1.4 Specify Study Objectives

The objectives of the BSCP are to provide background soils data for two soil populations. These populations are provided in the following list:

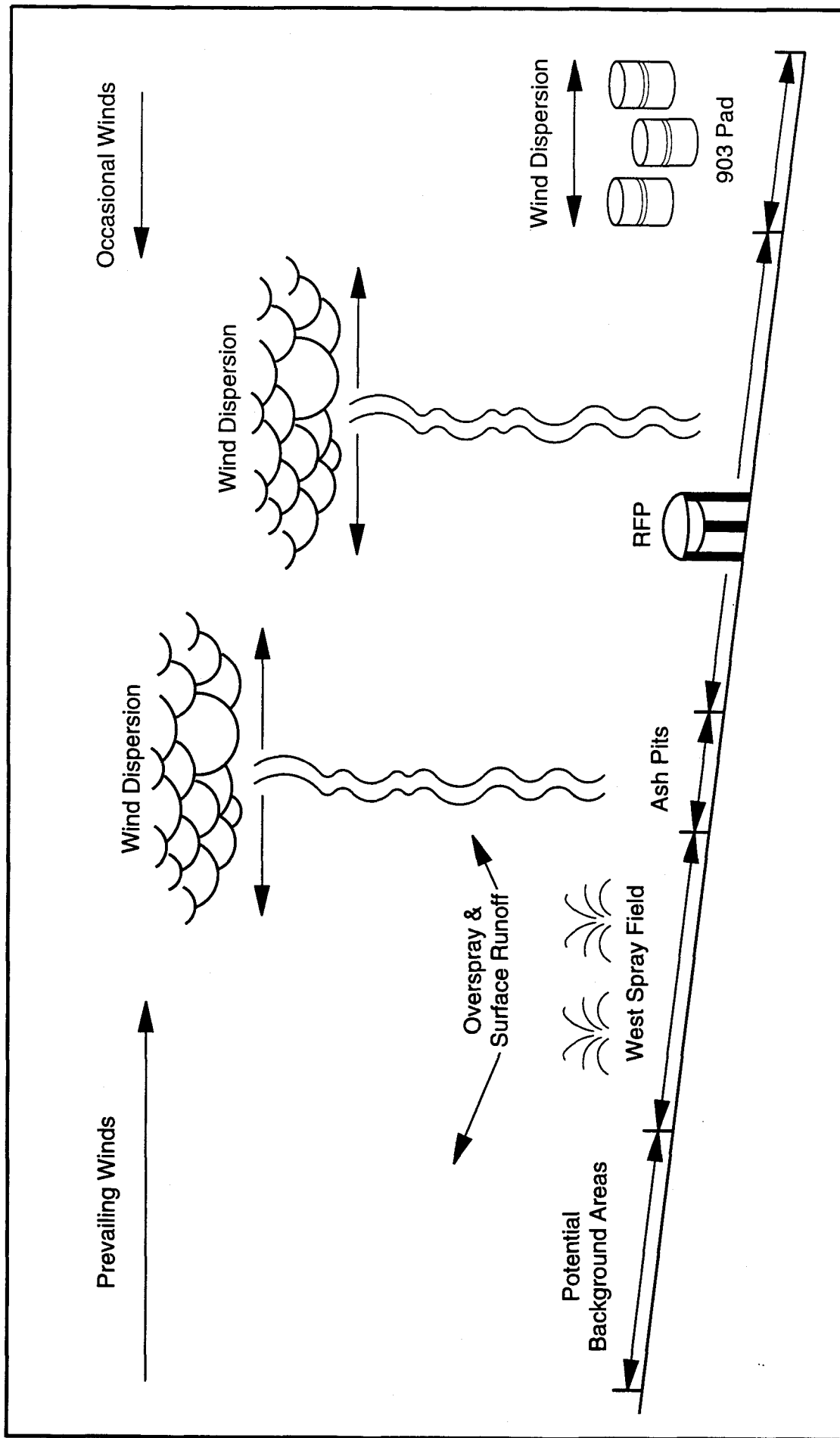
- The surface soil population [upper five cm (two in) of soil], including background concentration data of potential contaminants and physical/chemical parameters data



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FIGURE 4-4

SCHEMATIC CONCEPTUAL MODEL
 BACKGROUND AREAS & OFF-SITE
 SOURCES OF POTENTIAL
 CONTAMINANTS OF CONCERN



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FIGURE 4-5
 SCHEMATIC CONCEPTUAL MODEL
 BACKGROUND AREAS & RFP
 SOURCES OF POTENTIAL
 CONTAMINANTS OF CONCERN

- The soil profile population [upper 1.2 m (3.9 ft) of the soil], including general pedological (soil parameter) data, physical/chemical/mineralogical parameters in genetic horizons, and actinide concentration data (plutonium and americium) at incremental depths.

Specifying study objectives is linked to the identification of data uses and the determination of data types or analytes through the iterative DQO process. Data use and data types are discussed in Sections 4.2.1 and 4.2.2.

4.2 STAGE 2 - IDENTIFY DATA USES/NEEDS

The purpose of Stage 2 of the DQO process is to identify data uses and needs, evaluate sampling and analysis options, and review the PARCC parameters. As part of work plan preparation, Stage 2 was accomplished through five tasks:

- Identify Data Uses
- Identify Data Types
- Identify Data Quality Needs
- Identify Data Quantity Needs
- Review PARCC Parameter Information

Each of these tasks are described in the following sections.

4.2.1 Identify Data Uses

The BSCP is designed to be used by those concerned with present RCRA/CERCLA activities at RFP; however, it also anticipates future use by those concerned with feasibility studies and remedial action design and implementation, by those concerned with land use decision-making, by the scientific community, and by others who have an interest in background soils information.

The data uses for the BSCP that support RCRA/CERCLA activities include:

- Characterize site soils
- Determine the nature and extent of RFP contamination by comparing affected areas (OUs) with background

- Describe contaminant fate and transport
- Determine baseline risk assessment
- Evaluate remedial action alternatives
- Determine remedial action monitoring.

4.2.2 Identify Data Types

Data types necessary to meet the objectives of the BSCP include a broad spectrum of analytes. These analytes are in two broad categories:

- Potential soil contaminants such as radionuclides, metals, and organic compounds
- Physical/chemical/mineralogical/biological parameters needed to characterize the soil and to model contaminant fate and transport.

Some of the potential contaminants, such as the metals U and Ra, are naturally present in soils. Other potential contaminants such as Pu, Am, ^{137}Cs , $^{89/90}\text{Sr}$, and most of the organic contaminants, are present in soils only because of human activity.

Through the iterative DQO process, it became obvious that a reasonable approach to simplify the problem and meet the project objectives in the most cost-effective manner was to assemble the various data types into groups whose occurrence, behavior, data uses, and/or collection methods were similar. The following data groups were chosen.

- Fallout Group data types for surface soils
 - $^{239/240}\text{Pu}$
 - ^{241}Am
 - ^{137}Cs
 - $^{89/90}\text{Sr}$.

- Metals Group data types for surface soils
 - Total Analyte List (TAL) metals and Cs, Sr, Molybdenum (Mo), and Lithium (Li)
 - U and Ra isotopes
 - Physical/chemical parameters for surface soils.
- Organic Group data types for surface soils
 - TCL base-neutral extractable semivolatile compounds
 - TCL pesticides and PCBs.
- Soil profile group data types
 - TAL metals in genetic horizons
 - U and Ra in genetic horizons
 - Physical/chemical/mineralogical/biological parameters in genetic horizons
 - Actinides (Pu and Am) in depth increments
 - Soil ecology support
 - Pedological data.

4.2.3 Identify Data Quality Needs

Data quality needs are detailed in Section 7.3.6. Generally, data quality will be achieved by adhering to the data collection and analysis protocols provided in agency-approved EG&G Rocky Flats Environmental Management Department Operating Procedures (Volumes I through VI) and the General Radiochemistry and Routine Analytical Services Protocol (GRRASP), Parts A and B.

4.2.4 Identify Data Quantity Needs

Data quantity needs are typically related to the selection of statistical parameters (confidence and power), which are used in equations for estimating a sample size necessary to describe a population. These parameters are associated with the degree of error that is allowable in defining populations and are dependent on the ultimate use of the collected data, which is determining contaminants of concern (COCs) at OU investigations. Therefore, it would be appropriate that these parameters be based on the requirements of the statistical procedures

outlined by Gilbert and Simpson (1992), which have recently been approved for OU investigations. At the time of this study, Gilbert's recommendations of COC determination did not reveal data requirements for the background data (i.e., power). To accommodate this situation, this study assumed typical confidence and power values for making estimates of the necessary number of samples to adequately describe the background populations. Evaluation of data quantity needs for each analyte group is discussed in Section 4.3.

4.2.5 Review PARCC Parameter Information

PARCC parameters are indicators of data quality. The PARCC goals for samples collected in support of the BSCP are specified in Section 7.0, Quality Assurance Addendum. Section 4.3.1 discusses historical data comparability relevant to the development of the sampling design.

4.3 STAGE 3 - DESIGN DATA COLLECTION PROGRAM

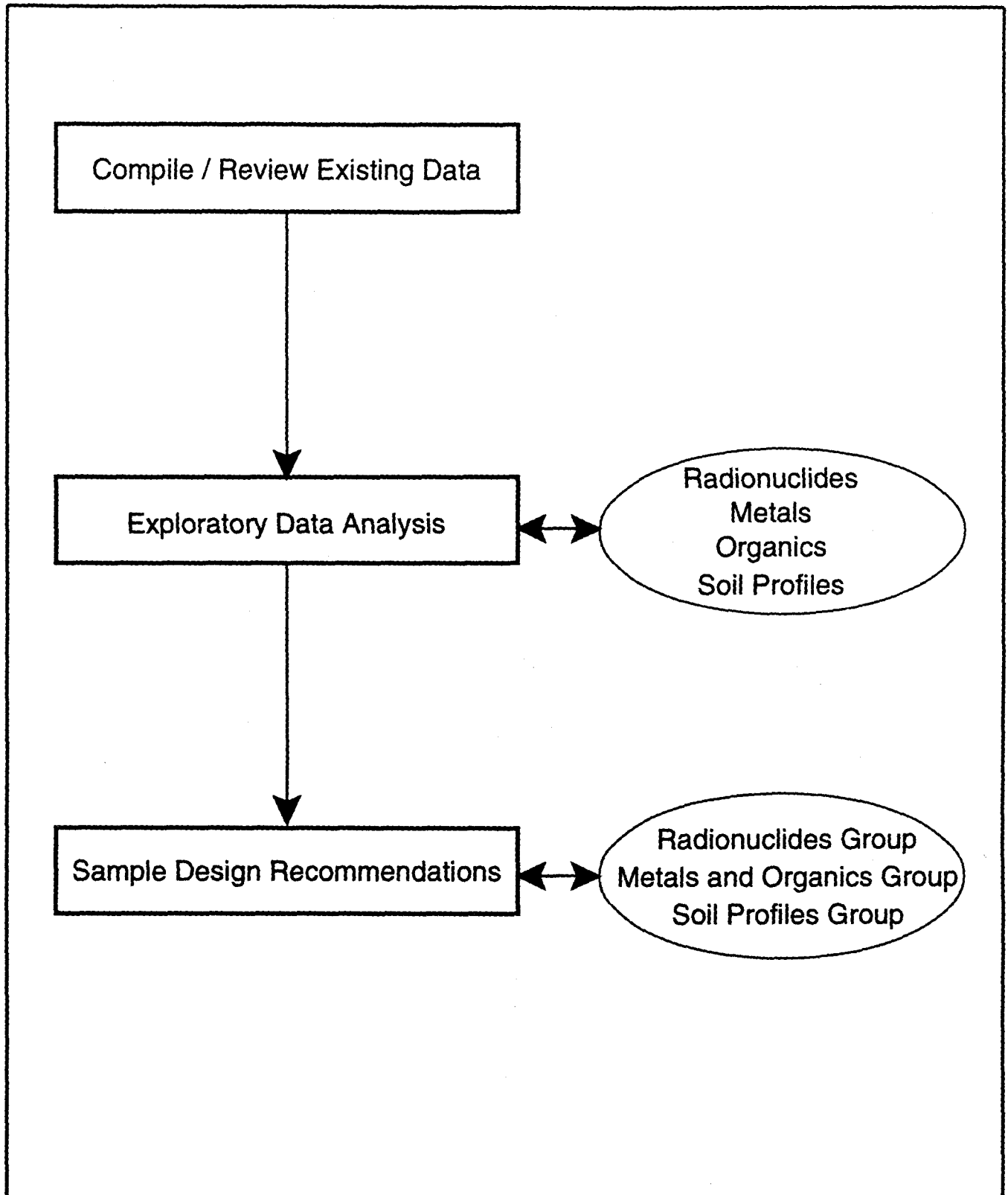
The purpose of Stage 3 of the DQO process is to integrate all components of the DQO process into a comprehensive sampling plan for all data types, which include:

- Fallout Group
- Metals Group
- Organics Group
- Soil Profiles Group.

Consideration of these data types in the sampling design development is introduced in Section 4.0 and is discussed further in Section 4.3.2, Design Approach.

Figure 4-6 illustrates the process for designing the data collection program for the background characterization of the upper five cm (two in) of soil. The initial step consisted of creating data sets for use in EDA. Data that provided an understanding of contaminant release and distribution patterns at RFP were compiled from select, previous investigations discussed in Section 3.0. The data sets were then subject to EDA to identify data gaps and to assess alternative sampling designs.

The following sections discuss the process of designing the data collection program. The design of the data collection program includes the review of existing data, EDA, and sample design recommendations for each analyte group.



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FIGURE 4-6

PROCESS FOR DESIGNING
DATA COLLECTION PROGRAM

4.3.1 Review of Pre-existing Data

The initial task of reviewing the existing data was to compile historical data sets in an electronic format. With the exception of $^{239/240}\text{Pu}$, the data compiled for this purpose were extracted from the Rocky Flats Environmental Database System (RFEDS). Data qualified as unusable (RFEDS validation code 'R') were excluded from the data sets. Sample duplicates and analytical replicates were averaged before analyses were performed. A usability assessment of the data was not performed (i.e., calculating PARCC parameters for the existing data). The $^{239/240}\text{Pu}$ data included analytical results from multiple sources (i.e., samples collected and analyzed by individuals and organizations other than RFP). A discussion of data comparability for the EDA follows.

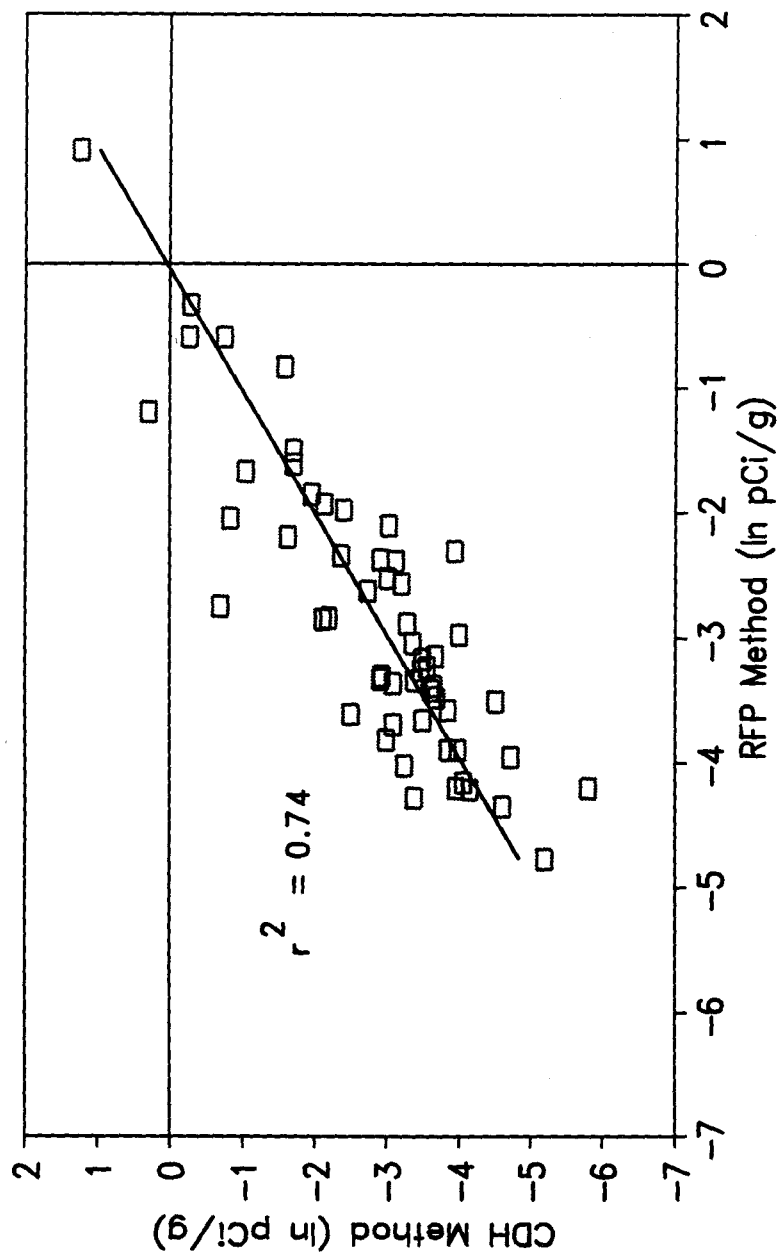
Since 1969, several methods were employed in the Rocky Flats region to sample soil for $^{239/240}\text{Pu}$ contamination. Initially, Krey and Hardy (1970) with the Health and Safety Lab of the Atomic Energy Commission (predecessor to DOE) sampled to a depth of 20 cm (7.9 in) in order to determine a complete inventory of plutonium in the soil. The CDH developed a method in which samples were collected to a depth of 0.64 cm (0.25 in), in order to assess the risk of Pu to human health. Pu is potentially respirable by resuspension of dust from soils. Poet and Martell collected samples in 1972 to a depth of one cm (0.4 in) for examining plutonium contamination. The resulting $^{239/240}\text{Pu}$ concentrations from these multiple sampling efforts are illustrated in Figure 4-7.

For the purpose of the EDA and the design of the sampling plan for fallout radionuclides, it was assumed that the historical $^{239/240}\text{Pu}$ data from surface soils were comparable. This decision was based on a comparison of $^{239/240}\text{Pu}$ results from samples collected by both the RF and the CDH sampling methods. Figure 4-8 illustrates this correlation. The data in Figure 4-8 are results from the OU3 RFI/RI. Thus, aggregation of the historical data sets provided an extensive data set, on-site and off-site, for the EDA.

4.3.2 Exploratory Data Analysis

Prior to the EDA, the background conceptual site model was reviewed to understand the general processes that may affect the sampling plan design. Because this study focused on several analyte groups, two general regions were considered as potential background soil sampling sites: (1) remote sites outside the range of potential atmospheric deposition resulting from RFP activities and (2) sites within RFP border in areas upwind of the industrial area. An advantage

CDH vs RFP Method Pu-239/240 (0U3)



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FIGURE 4-8
COMPARISON OF ^{239/240}Pu FROM
CDH AND RFP SAMPLING
METHODS FROM 0U3 DATA SET

of selecting sampling locations within RFP border is that pedogenic, geomorphic, and hydrologic characteristics of soils within individual OUs are similar to those characteristics of soils in the immediate vicinity of RFP. A disadvantage of selecting background sampling locations within RFP is the possibility that those sites may be contaminated by activities from RFP. The major issues for developing a background sampling plan design are:

- The areal extent of potential contamination due to RFP activities
- The potential variability of analyte concentrations in different soil types or geologic parent materials.

The sampling design approach was to group analytes which had similar data needs. Table 4-1 lists the issues to be investigated by the EDA for each analyte group. Sample design considerations for each analyte group follow.

Fallout Group

- The sample design is not primarily dependent on soil type or geologic parent material, because fallout radionuclides do not occur naturally in soil; therefore, a sample design located outside the range of RFP influence is applicable.
- The suitability of the Rock Creek drainage study as background should be assessed.

Metals Group

- A sample design distant from RFP may not be suitable due to the potential variability of metals concentrations in soil types and geologic parent materials dissimilar to RFP soils.
- The suitability of the use of the Rock Creek drainage study as background should be assessed.

TABLE 4-1

ANALYTE GROUPS AND CONSIDERATIONS FOR EXPLORATORY DATA ANALYSIS

| DATA TYPE GROUPS | CONSIDERATIONS FOR EXPLORATORY DATA ANALYSIS |
|------------------|--|
| Fallout | <ul style="list-style-type: none"> • Influence of RFP • Suitability of Rock Creek data set as background • Provide rationale for the placement of background sampling locations if necessary |
| Metals | <ul style="list-style-type: none"> • Influence of RFP • Geology/soil type • Suitability of Rock Creek data set as background • Provide rationale for the placement of background sampling locations if necessary |
| Organics | <ul style="list-style-type: none"> • Suitability of Rock Creek data set as background • Provide rationale for the placement of background sampling locations if necessary |
| Soil Profiles | <ul style="list-style-type: none"> • Provide rationale for the placement of background sampling locations |

Organics Group

- A sample design distant from RFP may not be suitable because of the potential influence from unknown off-site sources.
- The lack of quantifiable detections in the Rock Creek drainage study indicates that it has not been influenced by RFP or other off-site sources.

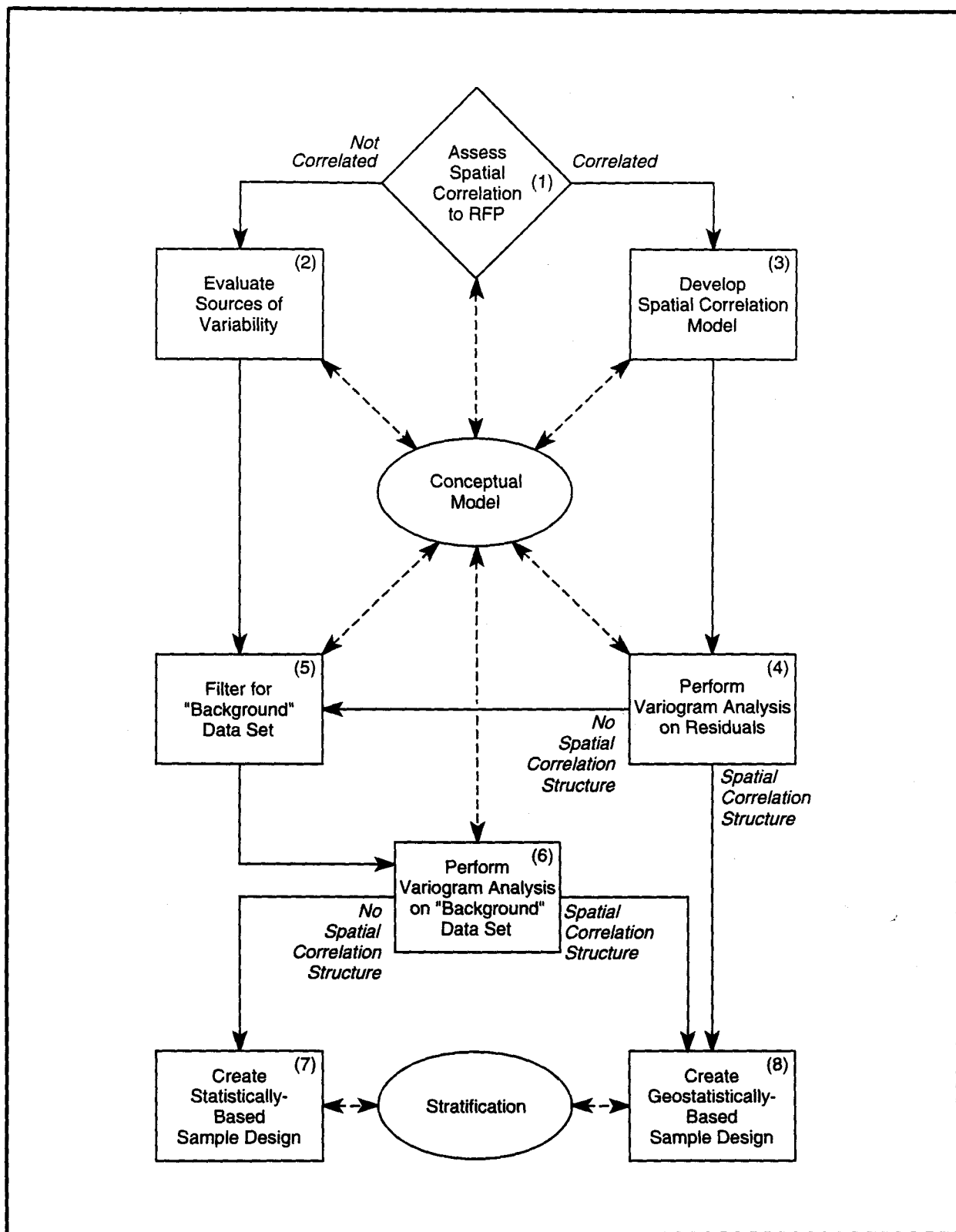
Soil Profile Group

- Sampling design component for the soil profile data type is based on soil type and slope position representative of those found at RFP.

For each analyte group, the EDA assumes windborne transport is the primary mechanism for off-site surface soil contamination. Therefore, it may be possible to correlate soil concentrations to wind patterns at RFP relative to a source location. This correlation may not be exact because the following factors may affect it.

- Topographic features
- Soil and vegetation type
- Method of sample collection and compositing
- Analytical method
- Proximity to human activities
- Prior and ongoing remedial activities
- Methodology for selecting sampling locations.

The goal of the EDA was to evaluate the available surface soil data at RFP and to use the information gained from this process to provide rationale for sampling design alternatives that are consistent with DQO. The EDA process is illustrated in Figure 4-9. The current understanding of site conditions is shown as "Conceptual Model" in Figure 4-9. The Conceptual Model (discussed in Section 4.1.3) is updated to incorporate the information gained during each step in the analysis.



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FIGURE 4-9
 FLOW CHART OF EXPLORATORY
 DATA ANALYSIS

The EDA was developed to address the specific issues relevant to the scope of this study. It is beyond the scope of this study to consider all possible factors contributing to soil chemistry in the vicinity of RFP. The EDA develops a "general understanding" of soil chemistry and the major factors contributing to metal concentrations and radionuclide activities near RFP. This general understanding was developed to aid in the sampling plan design rationale consistent with a level of detail appropriate to a reconnaissance investigation. The EDA was not intended to precisely delineate the extent of contamination resulting from RFP activities. A detailed discussion of all potential methods for evaluating sample design alternatives is beyond the scope of this study.

The following is a general discussion of the steps in the EDA (Figure 4-9). Each step of the EDA was developed as a result of an iterative process that identified groups of analytes (i.e., data types) that had differing data needs to adequately characterize background soil chemistry. By utilizing specific data types for the evaluation of existing data, the sampling plan designs become more manageable and representative of the actual data needs. An explanation of the EDA for each data group follows this general discussion.

Step 1. Assess Spatial Correlation to RFP

The underlying assumption of the EDA is that windborne transport is the primary mechanism for off-site surface soil contamination. Therefore, analytes, which have been identified in previous studies as potential windborne contaminants, are evaluated for spatial correlation relative to their suspected source.

A simple method is used to explore this potential relationship. The data is organized into sectors similar to the sectors of a wind-frequency diagram. The method consists of sorting data into eight sectors with the contaminant source as the origin. It is hypothesized that the windborne contaminants will display a strong correlation in the downwind direction relative to the source area. Plots of concentration versus distance from the source area are then produced for the analyte in each sector. Analytes that exhibit an apparent correlation are categorized as having spatial correlation to RFP. Analytes that exhibit no correlation are classified as having no spatial correlation to RFP.

Step 2. Evaluate Sources of Variability

Step 2 of the EDA considers the analytes that showed no spatial correlation to RFP. This step explores the possibility of soil chemistry dependence on naturally occurring factors, such as soil type and geologic parent material. For each analyte, the data is sorted by study area (i.e., OU2, OU3, etc.) and by soil type. Box-and-whisker plots are generated to observe potential variability attributable to soil type and geologic parent material.

Step 3. Develop Spatial Correlation Model

Step 3 of the EDA develops a model that describes the relationship of distance and direction for the analytes that exhibited spatial correlation to RFP. A simple algorithm is used to describe the trend in each sector plot from step 1. The algorithm is a median smoothing method and is described in detail by Tukey (1977) and advocated by Cressie (1991). The median smoothing technique is designed to reveal underlying trends in data sets masked by large variations. This algorithm is used because of its simplicity and its resistance to unusual or outlying data, ensuring that its results are not too sensitive to a small proportion of the data, some of which may be suspect.

Step 4. Perform Variogram Analysis of Residuals

Step 4 of the EDA continues with the analyte data set that exhibited spatial correlation to RFP. This step uses the median smoothing results to remove the trend in the data (i.e., the potential RFP influence). Residuals are the output of the trend removal process. A residual analysis is generally developed in stages and at each stage is re-expressed in the form of the following equation.

$$\text{VALUE} = \text{MODEL} + \text{FIT} + \text{RESIDUAL}$$

where:

VALUE is either an original datum or some simple mathematical transform (such as the logarithm).

MODEL is the value predicted at the preceding stage. Thus, multiple models can be used to explain the data and can be incorporated in an iterative process. For this analysis, the factors are distance and direction from the source and are incorporated in a single stage.

FIT is a value determined by a small number of parameters (i.e., the median smoothed fit).

RESIDUAL is whatever is left over to make the equation work.

The process stops when the residuals exhibit no pattern. That is, no important correlation with any factor can be identified and the residuals are symmetrically distributed about zero. "Important" means a correlation that materially reduces the variability of the residuals once the correlation is fit. The variability of the residuals should be made as small as possible. When this occurs, one can tentatively treat the residuals as realizations of identically distributed random variables representing forms of "error" or uncontrollable, natural, variability. To ensure that the trend has been removed from the data, the residuals are re-analyzed by the procedure in Step 1. If the model is appropriate, the residuals should be symmetrically distributed about zero.

It may still be possible to find a different kind of pattern--a probabilistic pattern--in the residuals. Rather than being independent random variables, they may exhibit correlation. The most likely form of correlation will depend on location. The statistical analysis of such behavior is properly the domain of geostatistics. Therefore, a variogram analysis of the residuals is performed to investigate the potential of an underlying spatial structure in the data, which may be attributable to background concentrations in the surface soils. If the variogram analysis reveals a spatial correlation, the estimated variogram(s) are used to aid the sampling plan design (Step 8).

Step 5. Filter for "Background" Data Set

Step 5 considers two potential analyses in the EDA. One analysis considers a data set that displays spatial correlation to RFP (Step 1) and the variogram analysis of residuals display no spatial structure (Step 4). For this component of Step 5, the sector plots and median smoothing results are revisited to estimate the influence of RFP on soil chemistry in each sector. The estimates of RFP influence by sector is based on professional

judgement. The estimated distances of RFP influence do not represent the actual extent of contamination due to RFP activities. These estimates are only used to filter for a "background" data set, which will be used to estimate the number of samples necessary to characterize the background population (Step 7). Samples outside the estimated distances are extracted from the data set to create the background data set.

The other component is a data set that showed no spatial correlation to RFP and is evaluated for the potential of soil chemistry dependence on naturally occurring factors, such as soil type and geologic parent material. For this component of Step 5, the Rock Creek data set is assumed to be unaffected by RFP activities and is representative of background conditions.

Step 6. Perform Variogram Analysis on "Background" Data Set

A variogram analysis of the filtered data set, defined in Step 5, is performed to evaluate the potential of a spatial correlation structure in background soil concentrations. If the variogram analysis reveals a spatial correlation, the estimated variogram(s) are used to aid the sampling plan design (Step 8).

Step 7. Create Statistically-Based Sample Design

Step 7 of the EDA utilizes the filtered background data sets to estimate the required number of samples to characterize background soil chemistry populations. Standard sample size estimate equations (EPA, 1989a) are used for estimating the required samples.

Suitable sampling regions are identified during the EDA process. Final sampling locations comply with stratification requirements necessary for each data group.

Step 8. Create Geostatistically-Based Sample Design

Step 8 of the EDA process is considered in the event a "background" data set exhibited spatial structure (Step 6) or if a residual analysis revealed an underlying spatial structure (Step 4). Flatman and Yfantis (1984) discuss design optimization for spatially correlated variables. In general, their recommended design strategy is a systematic grid. The grid shape is determined by the variogram: the grid shape is square if the directional

variograms have little anisotropy, or rectangular and rotated to correct the anisotropy and the grid length(s) are read from the empirical variogram as a function of tolerable variance in the output (kriging estimates) or a fraction (≤ 0.67) of the range.

The EDA for each analyte group (Section 4.3.2) found no apparent spatial structure (Steps 4 and 6). Thus, further discussion of the application of these techniques was excluded.

The following sections discuss the EDA for each analyte group. The EDA discussion proceeds according to the steps shown in Figure 4-9. Following the discussion of the EDA by analyte group, a summary of the EDA and sampling design recommendations are presented for each analyte group.

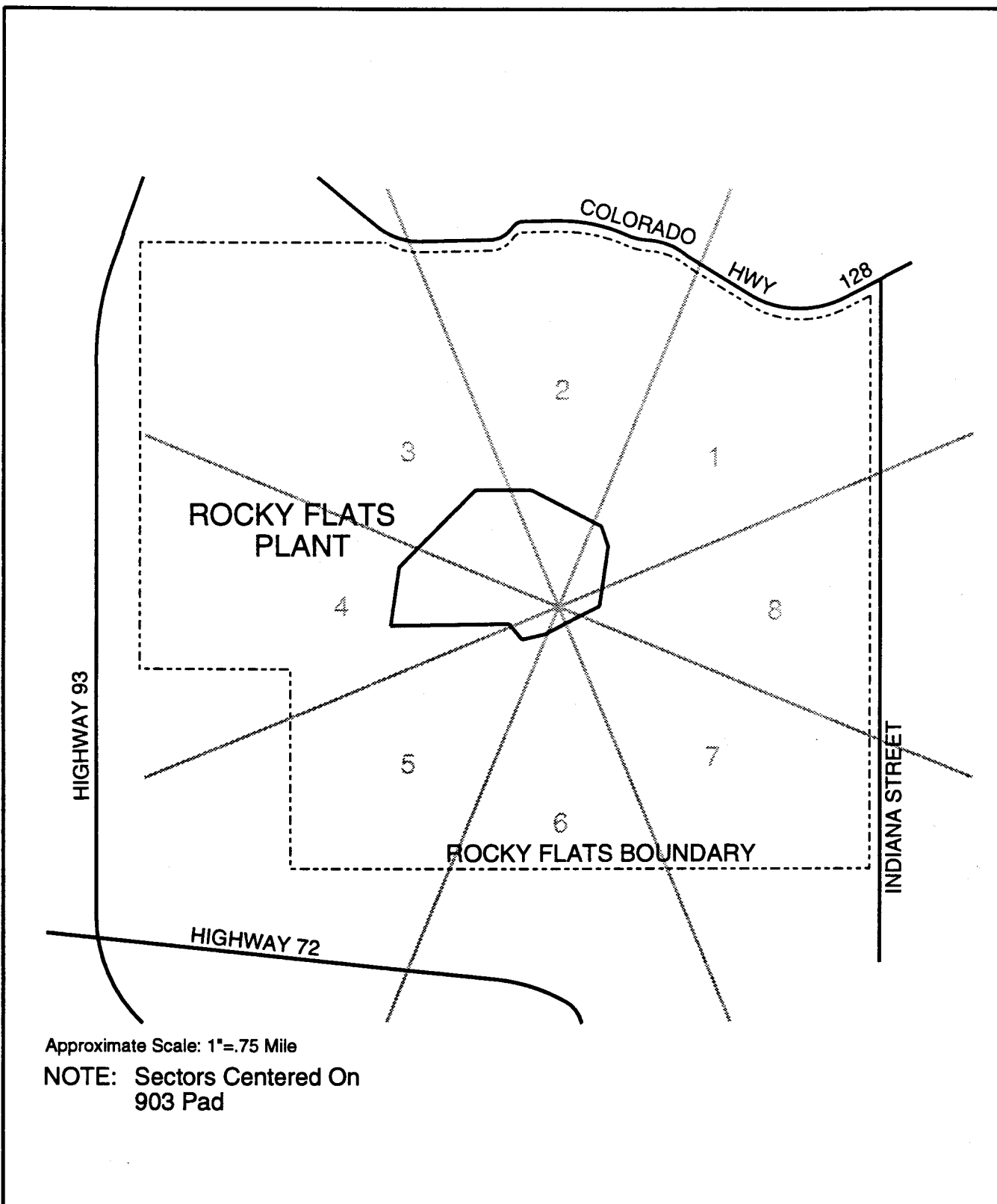
4.3.2.1 Fallout Group

As shown in Table 4-1, the objective of the fallout group EDA is to (1) assess the areal extent of fallout group contamination as a result of RFP activities, (2) evaluate the suitability of the Rock Creek data set as background, and (3) provide a rationale for the placement of background sampling locations, if necessary.

Plutonium-239/240 is the predominant concern for fallout group contamination in background areas as a result of RFP activities. Considering this concern and the fact that $^{239/240}\text{Pu}$ has the most extensive historical data base for both on-site and off-site locations, it seemed appropriate to use $^{239/240}\text{Pu}$ as an indicator for assessing the areal influence for the fallout group and subsequent sample design considerations listed in Table 4-1.

A visual inspection of the spatial distribution of $^{239/240}\text{Pu}$ from a compilation of most known sampling activities (Figure 4-7) indicates that the 903 Pad was the predominant source of $^{239/240}\text{Pu}$ contamination in surface soils. Thus, the EDA for $^{239/240}\text{Pu}$ focuses on the relationship of $^{239/240}\text{Pu}$ relative to the 903 Pad for surface soils.

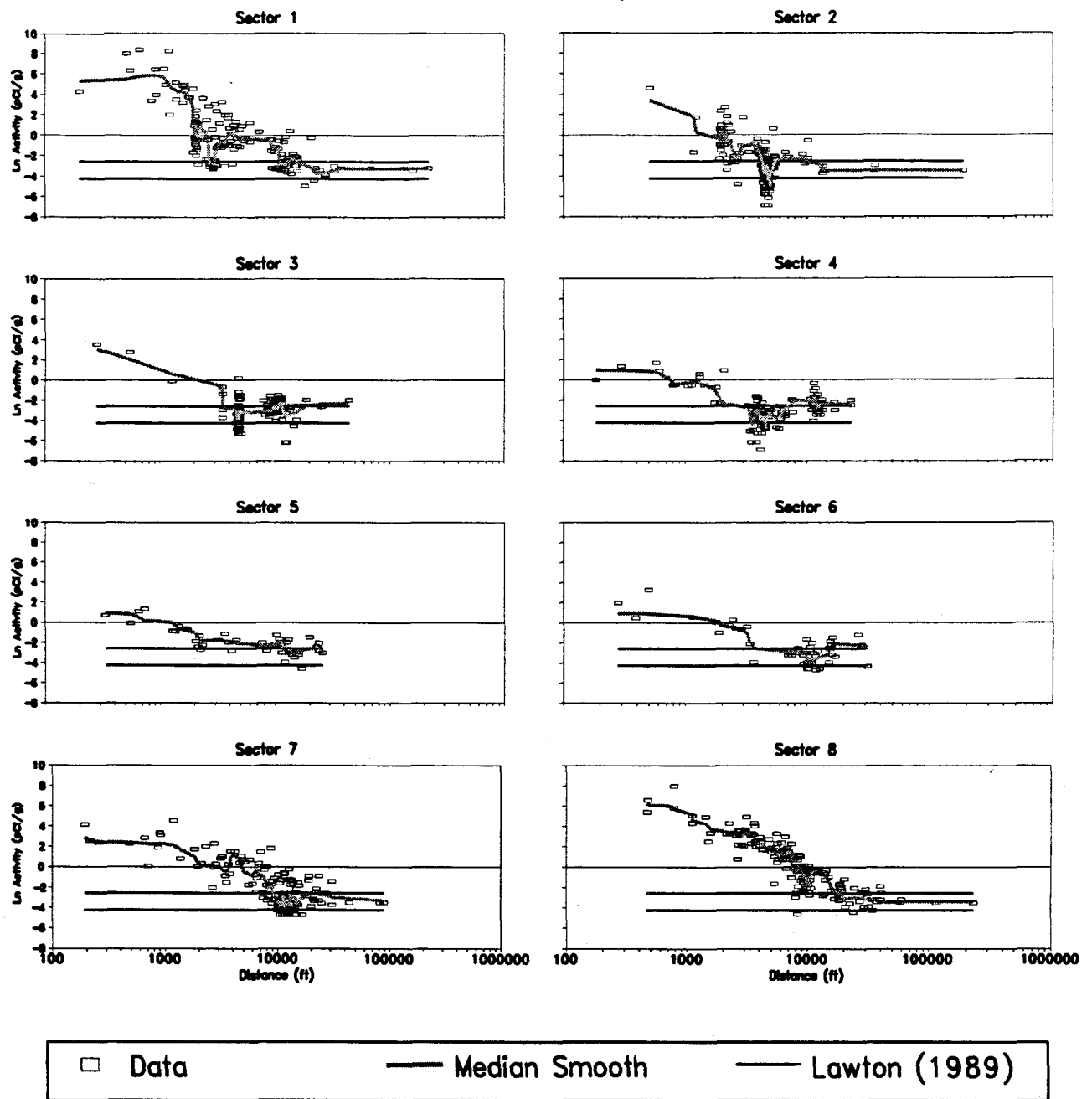
Step 1 of the EDA process (Figure 4-9) was applied to the $^{239/240}\text{Pu}$ data set to explore the potential relationship of $^{239/240}\text{Pu}$ and the 903 Pad. Eight sectors, corresponding to the sectors used to display wind data during 1953 through 1970 (from Krey and Hardy, 1970), were used to sort and group the $^{239/240}\text{Pu}$ data for inspection. Litaor (1993b) indicates that windborne dispersal of $^{239/240}\text{Pu}$ from the 903 Pad was effectively halted by the asphalt capping of the 903



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FIGURE 4-10
SECTOR ORIENTATION AND
LOCATION FOR
RADIONUCLIDE EDA

Plutonium 239/240



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FIGURE 4-11

Pu (pCi/g) VERSUS
DISTANCE IN SECTORS 1-8

Pad area in 1969. Figure 4-10 illustrates the orientation and location of the sectors used to sort the $^{239/240}\text{Pu}$ data. Figure 4-11 shows $^{239/240}\text{Pu}$ versus distance and median smoothing (Step 2 of EDA). For comparative purposes, Figure 4-11 shows the maximum and minimum $^{239/240}\text{Pu}$ ranges from Lawton (1989), in each sector. As suspected, the sectors downwind of the 903 Pad (sectors 1, 7, and 8) show elevated $^{239/240}\text{Pu}$ activities at large distances [approximately 6096 m (20,000 ft)] from the 903 Pad. The relationship of $^{239/240}\text{Pu}$ and distance in the remaining sector plots is less evident.

Sector 3 consists of $^{239/240}\text{Pu}$ data from OU7 and the Rock Creek data set. In sector 3, the median smooth fit shows the trend of $^{239/240}\text{Pu}$ activity dipping below the upper range of the Lawton (1989) data set before the distance where the Rock Creek data are located. However, the upper range of $^{239/240}\text{Pu}$ activity in the Rock Creek area is significantly above the maximum value in the Lawton (1989) study. The variability and upper range of $^{239/240}\text{Pu}$ activity in the Rock Creek area, combined with the lack of data at larger distances from the 903 Pad in sector 3, provides no clear basis for characterizing the Rock Creek data set as representing background for fallout radionuclides. Therefore, a remote sampling plan for Pu is appropriate.

Appendix B also contains box-and-whisker plots of radionuclide activity by sector for $^{89/90}\text{Sr}$, ^{137}Cs , and ^{241}Am . Am and Pu display a similar spatial correlation to the RFP. Cs and Sr, however, show no apparent spatial correlation to RFP, suggesting they are not a windborne contaminant.

Step 4 of the EDA process was applied to the $^{239/240}\text{Pu}$ data, using the median smoothing fit to remove the apparent trend (i.e., RFP influence) in the data. A variogram analysis, however, revealed no spatial correlation structure of residuals. Therefore, Step 5 of the EDA process was applied.

Step 5 of the EDA provided a rationale for the number of background samples necessary to characterize fallout radionuclides. Due to the lack of data at large distances in sectors 3, 4, 5, and 6, it was difficult to estimate the distance at which $^{239/240}\text{Pu}$ activities merge with background in these sectors. However, in sectors 1, 2, 7 and 8 the correlation was more evident. Therefore, only sectors 1, 2, 7, and 8 were considered in Step 5 of the EDA. $^{239/240}\text{Pu}$ samples outside the estimated distances within each sector were extracted from the data set to create the background data set. Summary statistics were then calculated from these data and applied to standard sample size estimate equations (EPA, 1989a). Table 4-2 contains the information for estimating the sample size, including typical confidence and power for the estimates. It should

TABLE 4-2

BACKGROUND Pu SAMPLE SIZE ESTIMATES

| STUDY | MEAN (PCI/G) | CV (%) | MAXIMUM (PCI/G) | MINIMUM (PCI/G) | ESTIMATED NUMBER OF SAMPLES |
|---------------------------|-----------------|-----------|--------------------|--------------------|-----------------------------------|
| EDA Unfiltered | 0.062 | 195 | 0.770 | 0.012 | 590 |
| EDA Filtered ^a | 0.036 | 43 | 0.080 | 0.012 | 28 |
| Lawton (1989) | 0.036 | 58 | 0.077 | 0.014 | 53 |

Estimated number of samples $\geq [(Z_{\alpha} + Z_{\beta})/D]^2 + 0.5 Z_{\alpha}^2$ (EPA, 1989a)

Confidence (α) = 80%

Power (β) = 95%

Z_{α} = Percentile for standard normal distribution such that $P(Z \geq Z_{\alpha}) = \alpha$

Z_{β} = Percentile for standard normal distribution such that $P(Z \geq Z_{\beta}) = \beta$

MDRD = 20% (Minimum Detectable Relative Difference)

D = MDRD/CV

CV = Mean/Standard Deviation

- Outlier values of 0.77, 0.24, and 0.15 were eliminated from the filtered "background" data set to estimate the number of samples to characterize background plutonium population.

be noted that three outliers (0.77, 0.24, and 0.15 pCi/g) were eliminated from the background data set after the filtering process. Removal of the outlier values, which were clearly not of the same population as the remaining data, decreased the variance of the data set by 88 percent and the resulting estimated sample sizes from 590 to 28. The total number of samples in the filtered data set after removal of outliers was 37. For comparative purposes, sample size estimates based on the Lawton (1989) study are also illustrated in Table 4-2. The estimated sample size required to characterize the $^{239/240}\text{Pu}$ population based on the Lawton data is 53. Because it was unclear as to the extent of influence of $^{239/240}\text{Pu}$ contamination as a result of RFP activities, remote sampling locations are recommended in order to be conservative in the sampling design approach for the fallout group. Approximately 50 remote sample locations should be chosen to address the issue of RFP influence and further characterize orographic and precipitation effects with respect to $^{239/240}\text{Pu}$ deposition along similar Front Range physical settings.

4.3.2.2 Metals Group

As shown in Table 4-1, the objective of the EDA for metals and naturally occurring radionuclide metals is to (1) assess the areal extent of metal contamination as a result of RFP activities, (2) evaluate the relationship of soil type and geologic parent material to metal concentrations, (3) assess the suitability of the Rock Creek data set as background, and (4) provide a rationale for the placement of background sampling locations, if necessary.

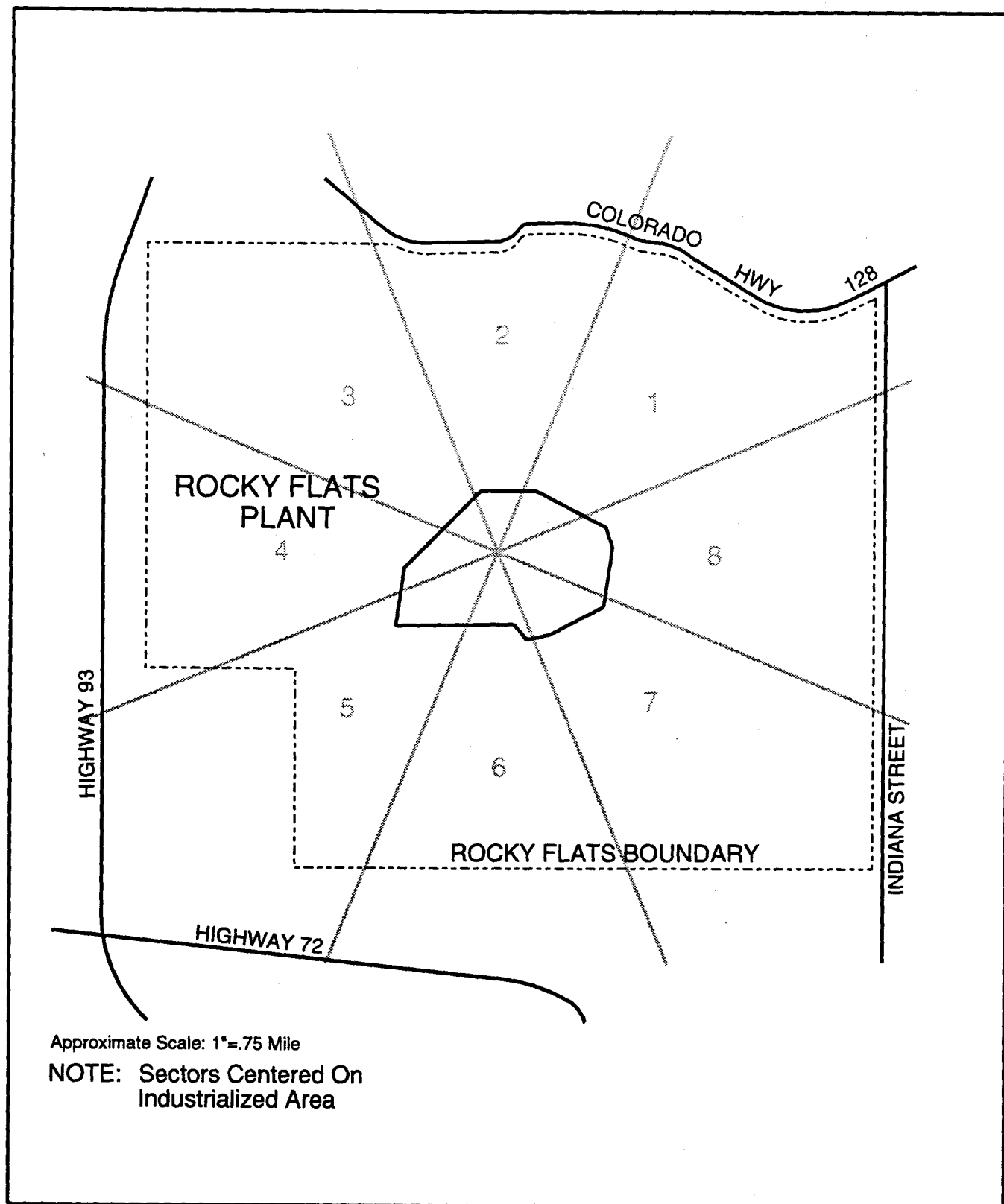
For metals, the potential for windborne contamination of surface soils is less clear. The Task 6 report (ChemRisk, 1993) lists arsenic (As), beryllium (Be), cadmium (Cd), chromium (Cr), lead (Pb), mercury (Hg), and nickel (Ni) as being potential contaminants as a result of RFP activities. Beryllium, however, is the only metal listed as a potential windborne contaminant resulting from general RFP activities. Therefore, the EDA for metals focuses on beryllium in surface soils but also includes the above mentioned metals. In addition to these seven metals, the EDA also explores Li, selenium (Se), ^{235}U and ^{238}U . Table 4-3 lists the rationale for considering these metals in the EDA.

The EDA for Be in surface soils considers describing its spatial relationship to RFP based on the proximity to the center of RFP industrial area (Step 1 of the EDA). Figure 4-12 illustrates the orientation and location of the sectors used to sort the Be data. Figure 4-13 shows Be versus distance and the median smoothing. For comparative purposes, Figure 4-13 shows the maximum and minimum Be ranges from Shacklette and Boerngen (1984), in each sector. The

TABLE 4-3

METALS CONSIDERED IN EXPLORATORY DATA ANALYSIS

| METAL | REASON FOR CONSIDERATION IN EXPLORATORY DATA ANALYSIS |
|---|---|
| Beryllium Lithium | <ul style="list-style-type: none">• Possible windborne contaminant as a result of RFP activities (ChemRisk, 1993) |
| Arsenic Cadmium Chromium Lead Mercury Nickel | <ul style="list-style-type: none">• Possible contaminant as a result of RFP activities (ChemRisk, 1993) |
| Selenium | <ul style="list-style-type: none">• Toxicity |
| ²³⁵ Uranium ²³⁸ Uranium | <ul style="list-style-type: none">• Naturally occurring metal/radionuclide• Possible windborne contaminant• Possible contaminant as a result of RFP activities (ChemRisk, 1993) |

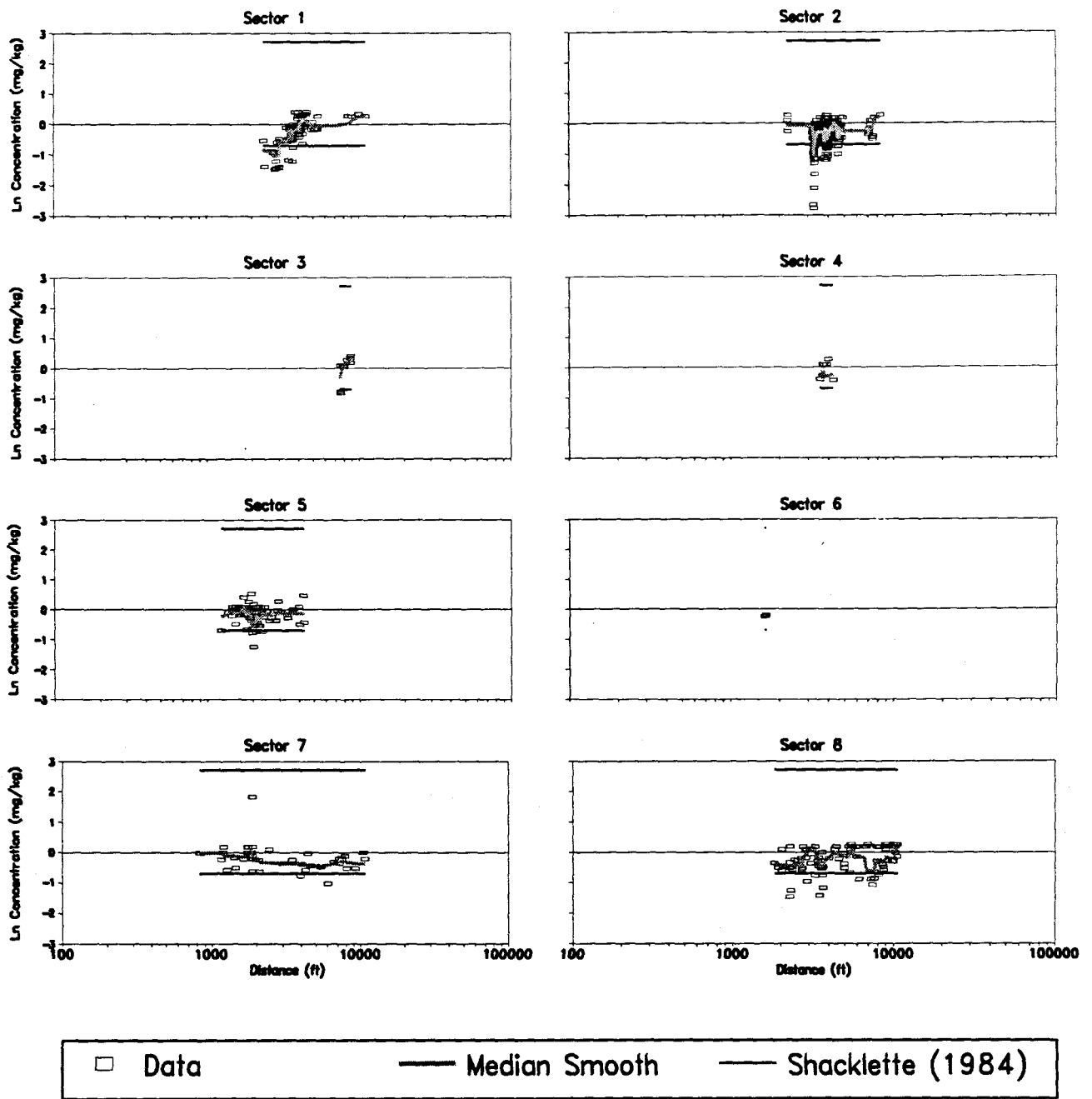


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FIGURE 4-12

SECTOR ORIENTATION AND
LOCATION FOR METAL EDA

Beryllium



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FIGURE 4-13

BERYLLIUM VERSUS
DISTANCE IN SECTORS 1-8

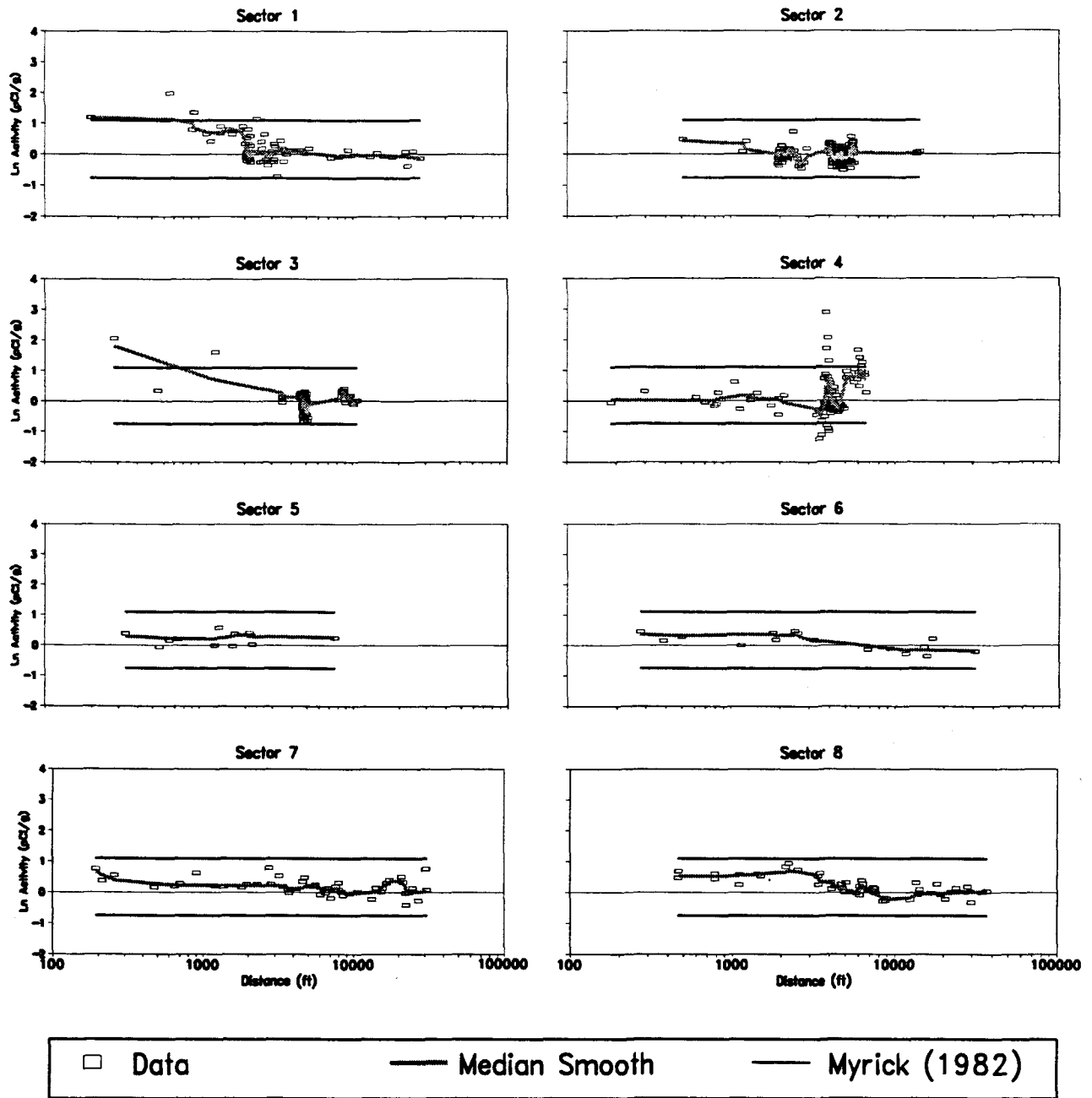
median smooth curve reveals no discernable correlation of Be with distance from the center of RFP.

Appendix C contains box-and-whisker plots of the Be data by sector. Consistent with the preceding plutonium analysis, it would be expected that the downwind sectors (1, 7, and 8) would contain elevated levels of Be in surface soils if it was a windborne contaminant. However, these plots indicate a consistent range of Be concentrations, in each sector, with the exception of a single outlier. Therefore, there is no evidence to suggest that Be is a windborne contaminant and that the Rock Creek drainage has been affected by RFP activities for Be. Box-and-whisker plots of metal concentration by sector, for the remaining metals, are also presented in Appendix C.

Step 2 was performed on the Be to evaluate the potential variability of Be between soil types. Box-and-whisker plots, organized according to the major soil types are also presented in Appendix C. In general, each metal is grouped by study and by soil type. For simplicity in observing the metals data, each metal was also grouped first by soil type and then by study. This analysis did not reveal a significant difference between soil types for the metals analyzed. For each metal, significant variations in concentration ranges can be explained by a comparison between studies (i.e., a particular OU contributed the larger metals concentrations). Thus, based on available data, stratification of background sampling by soil type did not appear as a necessity for characterization of background surface soil.

Naturally occurring ^{235}U and ^{238}U were also analyzed similarly to the metals analysis. The spatial analyses for the U isotopes, however, was performed relative to proximity to the 903 Pad (Step 1 of EDA). Figure 4-10 illustrates the orientation and location of the sectors used to sort the ^{235}U and ^{238}U data. Figure 4-14 shows ^{238}U versus distance and median smoothing. For comparative purposes, Figure 4-14 shows the ^{238}U range from literature compiled from Colorado locations, for each sector. No correlation was found in the ^{235}U data and is subsequently not presented. Sector 3 contains the ^{238}U data for the Rock Creek data set. It is clear from these plots that a relationship of distance from the 903 Pad exists with the ^{238}U . Unlike $^{239/240}\text{Pu}$, however, the downwind ^{238}U activities quickly drop and level-off well within the ^{238}U range compiled from literature. Data from sector 3 also are consistently within the literature range with the exception of two points proximal to the 903 Pad. These two points are not, however, part of the Rock Creek data set. Sector 4 shows elevated ^{238}U activities which correspond to OU5. Thus, the EDA reveals no evidence that suggest the Rock Creek drainage has been affected by RFP activities for naturally occurring U.

Uranium 235



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FIGURE 4-14

URANIUM-235 VERSUS
DISTANCE IN SECTORS 1-8

Step 2 was performed on the naturally occurring U data to evaluate the potential variability between soil types. Step 2 of the EDA presents ^{235}U and ^{238}U data in box-and whisker plots relative to study and soil type (see Appendix C). Examination of these plots reveal elevated activities in OU5 and no significant correlation to soil type. Thus, based on available data, stratification of background sampling by soil type does not appear as a necessity for characterization of background surface soil.

Since the metals EDA suggests that there is no evidence indicating that the Rock Creek data have been affected by RFP activities, the Rock Creek data are considered representative of background conditions at RFP (Step 5). A variogram analysis was performed on these data (Step 6) and revealed no spatial correlation structure.

For step 7 of the EDA, the Rock Creek data were used to estimate the number of samples required to characterize background metals. Summary statistics were calculated from these data and applied to standard sample size estimate equations (EPA, 1989a). Table 4-4 contains the information for estimating the sample size, including typical confidence and power for the estimates. Eleven of the 12 metals analyzed indicate a maximum 14 samples necessary for characterizing the background population. The Rock Creek data set has 18 data points for metals; therefore, this analysis would indicate that the Rock Creek data set is sufficient. However, ^{235}U requires 33 samples to characterize background. It should be noted that a single outlier (0.12 pCi/g), determined from a visual inspection of box-and-whisker plots, was eliminated from the ^{235}U data set. The Rock Creek data contains 16 ^{235}U sample locations. Therefore, a minimum of 17 additional samples randomly located in similar pedogenic and geomorphic conditions to those found at the OUs on-site should be collected.

4.3.2.3 Organics Group

The infrequency of detection for organic compounds precluded any meaningful EDA or statistical analysis to provide a rationale for the location and number of background organic samples to collect. As indicated in Section 3, Previous Investigations, the purpose of evaluating the site-specific studies with respect to the organic chemical data was to examine background concentration ranges for future RCRA/CERCLA decision-making. Most of the chemicals detected appear to be associated with non-point source contamination. PAHs, phthalate esters, and pesticides are characteristic of anthropogenic background and their concentration ranges are dependent upon the land use in the area. This information was considered when developing a sampling design.

TABLE 4-4
BACKGROUND METALS SAMPLE SIZE ESTIMATES

| METAL | CV (%) | ESTIMATED NUMBER OF SAMPLES |
|---|--------|-----------------------------|
| Arsenic | 31 | 12 |
| Beryllium | 26 | 8 |
| Cadmium | 35 | 14 |
| Chromium | 18 | 5 |
| Lead | 16 | 4 |
| Lithium | 21 | 6 |
| Mercury | 33 | 13 |
| Nickel | 29 | 10 |
| Selenium | 31 | 11 |
| ^{233/234} Uranium | 14 | 4 |
| ²³⁵ Uranium | 54 | 33 ^a |
| ²³⁸ Uranium | 16 | 4 |
| Maximum Estimated Samples = 33 Additional Samples Required = 17 ^b | | |

Estimated number of samples $\geq [(Z_{\alpha} + Z_{\beta})/D]^2 + 0.5 Z_{\alpha}^2$ (EPA, 1989a)

Confidence (α) = 80%

Power (β) = 90%

Z_{α} = Percentile for standard normal distribution such that $P(Z \geq Z_{\alpha}) = \alpha$

Z_{β} = Percentile for standard normal distribution such that $P(Z \geq Z_{\beta}) = \beta$

MDRD = 20% (Minimum Detectable Relative Difference)

D = MDRD/CV

CV = Mean/Standard Deviation

^a Outlier value of 0.12 eliminated from Rock Creek data set to estimate the number of samples characterize background U-235 population.

^b Value obtained by subtracting number of Rock Creek samples from estimated number (33 - 16 = 17).

As previously discussed, a detailed EDA was not appropriate for organic compounds due to the small number of detects in the Rock Creek data set and across the site. Therefore, to supplement the Rock Creek data for organics, the metals sample locations will also be analyzed for organics.

4.3.2.4 Soil Profile Group

The primary objective of the soil profile sampling is to provide baseline soils characterization of natural soils similar to those found in affected areas at RFP. Similar characterizations at other DOE facilities (Oak Ridge, Hanford, Savannah River Site) have generally employed a limited number of sampling locations for each of the major soil groups. In order to provide cost-effective, useful baseline soil characterization data, the BSCP will collect samples from approximately 15 to 20 backhoe excavated soil pits from the soil-landscape-geologic associations discussed in Section 2.6.5.

4.3.3 Summary of Exploratory Data Analysis and Sample Design Recommendations

This section presents a summary of the EDA for the analyte groups and the recommendations for sampling designs based on these results.

4.3.3.1 Fallout Group Sampling

From the EDA it was shown that a remote sampling design is appropriate for characterizing background fallout radionuclides in surface soils. Table 4-5 lists the sample design recommendations. Approximately, 50 remote sampling locations are recommended. In addition to being remote to RFP, these areas control for :

- Precipitation similar to RFP area [approximately 38 to 41 cm (15 to 16 in) per year]
- Land use (undisturbed grassland).

Section 5.0 discusses the sampling plan and analyte list for the fallout group in detail.

TABLE 4-5

SURFICIAL SOIL SAMPLE DESIGN RECOMMENDATION BY ANALYTE GROUP

| DATA TYPE GROUPS | SAMPLING DESIGN CONSIDERATIONS | SAMPLING DESIGN RECOMMENDATIONS | SAMPLES PER STRATIFICATION GROUP | TOTAL SAMPLE LOCATIONS |
|------------------|--|--|---|------------------------|
| Fallout group | <ul style="list-style-type: none"> • Outside RFP influence • Precipitation • Land use | <ul style="list-style-type: none"> • Farfield • Stratified random sampling | Not Applicable ¹ | 50 |
| Metals group | <ul style="list-style-type: none"> • Geology/soil type • Land use | <ul style="list-style-type: none"> • Stratified random sampling | Soil Type Drainage Bottom 6 Pediment Surface 7 Valley Slopes 7 | 20 |
| Organics group | <ul style="list-style-type: none"> • Land use | | | |

¹ The process of identifying suitable sampling areas is ongoing. Refer to Section 5.1 for the selection criteria for sample locations for fallout radionuclides.

4.3.3.2 Metals and Organics Group Sampling

As discussed in Section 4.3.2.3, the metals and organics sampling activity has been combined. For metals, the EDA (Section 4.1.2) did not indicate that the Rock Creek data had been affected by RFP activities. Therefore, a sample design in the vicinity of the Rock Creek data set is recommended. The metals EDA also showed no indication for stratification by soil type. However, it is recommended to locate additional background samples in similar pedogenic and geomorphic conditions to those found at the OUs on-site. Similar surface deposits and soil types are found on three representative landforms: pediments, valley slopes, and drainage bottoms. The Rock Creek data set has located nine samples on south aspect valley slopes, three on the pediment shoulder, and six on the pediment surface. Approximately 20 samples, in addition to the Rock Creek data set, was estimated to be adequate. In order to represent the previously mentioned strata, six samples shall be randomly located in the drainage bottoms, seven on the pediment surface, and seven on the valley slopes. Table 4-5 contains the recommendations for the metals sample design.

To supplement the Rock Creek data for organics, the metals sample locations will also be analyzed for organics. Table 4-5 contains the recommendations for the organics sample design. Section 5 discusses the sampling plan for metals and organics in more detail. Section 5 also lists the metals and organics that will be analyzed.

4.3.3.3 Soil Profile Group Sampling

Precedent for a soil profile sampling technique has been established in studies directed by M. I. Litaor for OU1, OU2, OU3, and OU6 regarding soil pedogenesis and vertical distribution of actinides in soil, and is outlined in EMD-OP Volume III GT.07. This sampling technique is generally consistent with USDA-SCS soil profile description techniques and shall meet the requirements for meeting the objectives for the soil profile data type. Design recommendations for soil profile sampling are a combination of judgmental and stratified random sampling. These designs are recommended to utilize professional judgment for selecting representative soil taxonomic families and ecological map units. In general, the soil profile sampling will be located on-site, upwind and upgradient of industrial area of RFP. Section 5 discusses the soil profile sampling in more detail.



5.0 FIELD SAMPLING PLAN

The sampling design presented in this section is composed of three soil sampling activities:

- Fallout group surface soil sampling
- Metals and organic groups surface soil sampling
- Soil profile sampling.

Each activity is described in Subsections 5.1, 5.2, and 5.3. Field quality control samples are discussed in Section 5.4. Table 5-1 identifies the Environmental Management Division (EMD) Operating Procedures (OPs) to be used during implementation of the BSCP field program. Tables 5-2, 5-3, and 5-4 list the analytes for samples collected for each sampling activity.

5.1 FALLOUT GROUP SURFACE SOIL SAMPLING

This section presents the field sampling plan for surface soil fallout radionuclides. This section includes the following elements:

- Selection of sampling locations
- Sampling method.

5.1.1 Selection of Sampling Locations

This sampling activity was designed to characterize the background concentrations in surface soils for radionuclides generated by fallout. The specific radionuclides of interest include $^{239/240}\text{Pu}$, ^{241}Am , ^{137}Cs , and $^{89/90}\text{Sr}$. Based on the conceptual model and the exploratory data analysis (Section 4.0), the identification of potential sampling locations is conditional to the following location criteria:

- Remote to RFP
- East of the Rocky Mountain Front Range
- Precipitation similar to RFP (approximately 15 to 16 inches per year)
- Undisturbed or least disturbed areas similar to rangeland areas at RFP
- Land access.

TABLE 5-1

EMD OPERATING PROCEDURES AND FIELD ACTIVITY MATRIX

| EMD OPS REFERENCE NUMBER | OPERATING PROCEDURE TITLE | SOIL SURVEY FALLOUT RADIONUCLIDES | SOIL SURVEY METALS/ORGANICS | SOIL PROFILE |
|--------------------------------|---|---|--------------------------------|-----------------|
| FO.02 | Field Document Control | • | • | • |
| FO.03 | General Equipment Decontamination | • | • | • |
| FO.04 | Heavy Equipment Decontamination | | | • |
| FO.06 | Handling of Personal Protective Equipment | X | X | X |
| FO.07 | Handling of Decontamination Water & Wash Water | | | • |
| FO.09 | Handling of Residual Samples | • | • | • |
| FO.11 | Field Communications | • | • | • |
| FO.12 | Decontamination Facility Operations | | | • |
| FO.13 | Containerizing, Preserving, Handling, and Shipping of Soil and Water Samples | • | • | • |
| FO.14 | Field Data Management | • | • | • |
| FO.18 | Environmental Sample Radioactivity Content Screening | | | • |
| GT.07 | Logging and Sampling of Test Pits and Trenches | | | • |
| GT.08 | Surface Soil Sampling | • | • | |
| GT.17 | Land Surveying | • | • | • |

X = Dependent on HASP Requirements

TABLE 5-2

ANALYTE LIST FOR FALLOUT GROUP

| Fallout Group | |
|------------------------------|--|
| Fallout Radionuclides | |
| ²⁴¹ Americium | |
| ¹³⁷ Cesium | |
| ^{239/240} Plutonium | |
| ^{89/90} Strontium | |
| Physical Parameters | |
| Bulk Density | |
| Particle Size Distribution | |

x COC

TABLE 5-3

ANALYTE LIST FOR METALS AND ORGANICS GROUP

| METALS GROUP | | | |
|--|---|-----------------------------|----------------------------|
| Target Analyte List (Metals) | | | |
| Aluminum | Chromium | Manganese, Total | Strontium* |
| Antimony | Cobalt | Mercury | Thallium |
| Arsenic | Copper | Molybdenum* | Tin* |
| Barium | Cyanide | Nickel | Vanadium |
| Beryllium | Iron, Total | Potassium | Zinc |
| Cadmium | Lead | Selenium | |
| Calcium | Lithium* | Silver | |
| Cesium* | Magnesium | Sodium | |
| Naturally Occurring Radionuclides Metals | | | |
| ^{233,234} Uranium | ²³⁸ Uranium | ²²⁶ Radium | |
| ²³⁵ Uranium | ²²⁶ Radium | | |
| Chemical Parameters/Physical Properties | | | |
| Ammonia | Oil and Grease | pH | Bulk Density |
| Nitrate/Nitrite | Carbonate | Specific Conductance | Particle Size Distribution |
| Total Organic Carbon | | | |
| ORGANICS GROUP | | | |
| Target Compound List (Semivolatiles) | | | |
| Phenol | bis(2-Chloroethoxy)methane | Acenaphthene | Fluoranthene |
| bis(2-Chloroethyl)ether | 2,4-Dichlorophenol | 2,4-Dinitrophenol | Pyrene |
| 2-Chlorophenol | 1,2,4-Trichlorobenzene | 4-Nitrophenol | Butylbenzylphthalate |
| 1,3-Dichlorobenzene | Naphthalene | Dibenzofuran | 3,3'-Dichlorobenzidine |
| 1,4-Dichlorobenzene | 4-Chloroaniline | 2,4-Dinitrotoluene | Benzo(a)anthracene |
| Benzyl alcohol | Hexachlorobutadiene | Diethylphthalate | Chrysene |
| 1,2-Dichlorobenzene | 4-Chloro-3-methylphenol (para-chloro-meta-cresol) | 4-Chlorophenyl-phenyl ether | bis(2-Ethylhexyl)phthalate |
| 2-Methylphenol | 2-Methylnaphthalene | Fluorene | Di-n-octylphthalate |

TABLE 5-3 (CONCLUDED)

ANALYTE LIST FOR METALS AND ORGANICS GROUP

| Semivolatiles (Concluded) | | | |
|--|---------------------------|----------------------------|------------------------|
| bis(2-Chloroisopropyl)ether | Hexachlorocyclopentadiene | 4-Nitroaniline | Benzo(b)fluoranthene |
| 4-Methylphenol | 2,4,6-Trichlorophenol | 4,6-Dinitro-2-methylphenol | Benzo(k)fluoranthene |
| N-Nitroso-di-n-propylamine | 2,4,5-Trichlorophenol | N-nitrosodiphenylamine | Benzo(a)pyrene |
| Hexachloroethane | 2-Chloronapthalene | 4,-Bromophenyl-phenylether | Indeno(1,2,3-cd)pyrene |
| Nitrobenzene | 2-Nitroaniline | Hexachlorobenzene | Dibenz(a,h)anthracene |
| Isophorone | Dimethylphthalate | Pentachlorophenol | Benzo(g,h,i)perylene |
| 2-Nitrophenol | Acenaphthylene | Phenanthrene | |
| 2,4-Dimethylphenol | 2,6-Dinitrotoluene | Anthracene | |
| Benzoic acid | 3-Nitroaniline | Di-n-butylphthalate | |
| Target Compound List (Pesticides and PCBs) | | | |
| alpha-BHC | Endosulfan I | Methoxychlor | AROCLOR-1232 |
| beta-BHC | Dieldrin | Endrin Ketone | AROCLOR-1242 |
| delta-BHC | 4,4'-DDE | alpha-Chlordane | AROCLOR-1248 |
| gamma-BHC (Lindane) | Endosulfan II | gamma-Chlordane | AROCLOR-1254 |
| Heptachlor | 4,4'-DDD | Toxaphene | AROCLOR-1260 |
| Aldrin | Endosulfan Sulfate | AROCLOR-1016 | |
| Heptachlor Epoxide | 4,4'-DDT | AROCLOR-1221 | |

* Non-TAL metals

TABLE 5-4

ANALYTE LIST FOR SOIL PROFILE SAMPLING ACTIVITY

| SOIL PROFILE GROUP | | | |
|---|------------------------------|------------------------|-----------------------|
| Target Analyte List (Metals) in Genetic Horizon | | | |
| Aluminum | Cesium* | Magnesium | Silver |
| Antimony | Chromium | Manganese, Total | Sodium |
| Arsenic | Cobalt | Mercury | Strontium* |
| Barium | Copper | Molybdenum* | Thallium |
| Beryllium | Iron, Total | Nickel | Tin* |
| Cadmium | Lead | Potassium | Vanadium |
| Calcium | Lithium* | Selenium | Zinc |
| Naturally Occuring Radionuclide Metals in Genetic Horizon | | | |
| ^{233,234} Uranium | ²³⁸ Uranium | ²³⁵ Uranium | ²²⁶ Radium |
| ²²⁸ Radium | | | |
| Physical/Chemical Parameters in Genetic Horizon | | | |
| Soil Profile Descriptions | Cation Exchange Capacity | Moisture Content | Nitrate/Nitrite |
| Soil Horizon Descriptions | Major Exchangeables | % Solids | Ammonia |
| Bulk Soil Density | Clay Mineralogy | Nutrients | Total Organic Carbon |
| Particle Size Distribution | Calcium Carbonate | Microorganisms | |
| Specific Surface | Sesquioxides | Carbonate | |
| Specific Conductance | Infiltration Rate | pH | |
| Actinides in Depth Increments | | | |
| ²⁴¹ Americium | ^{239/240} Plutonium | | |

* Non-TAL metals

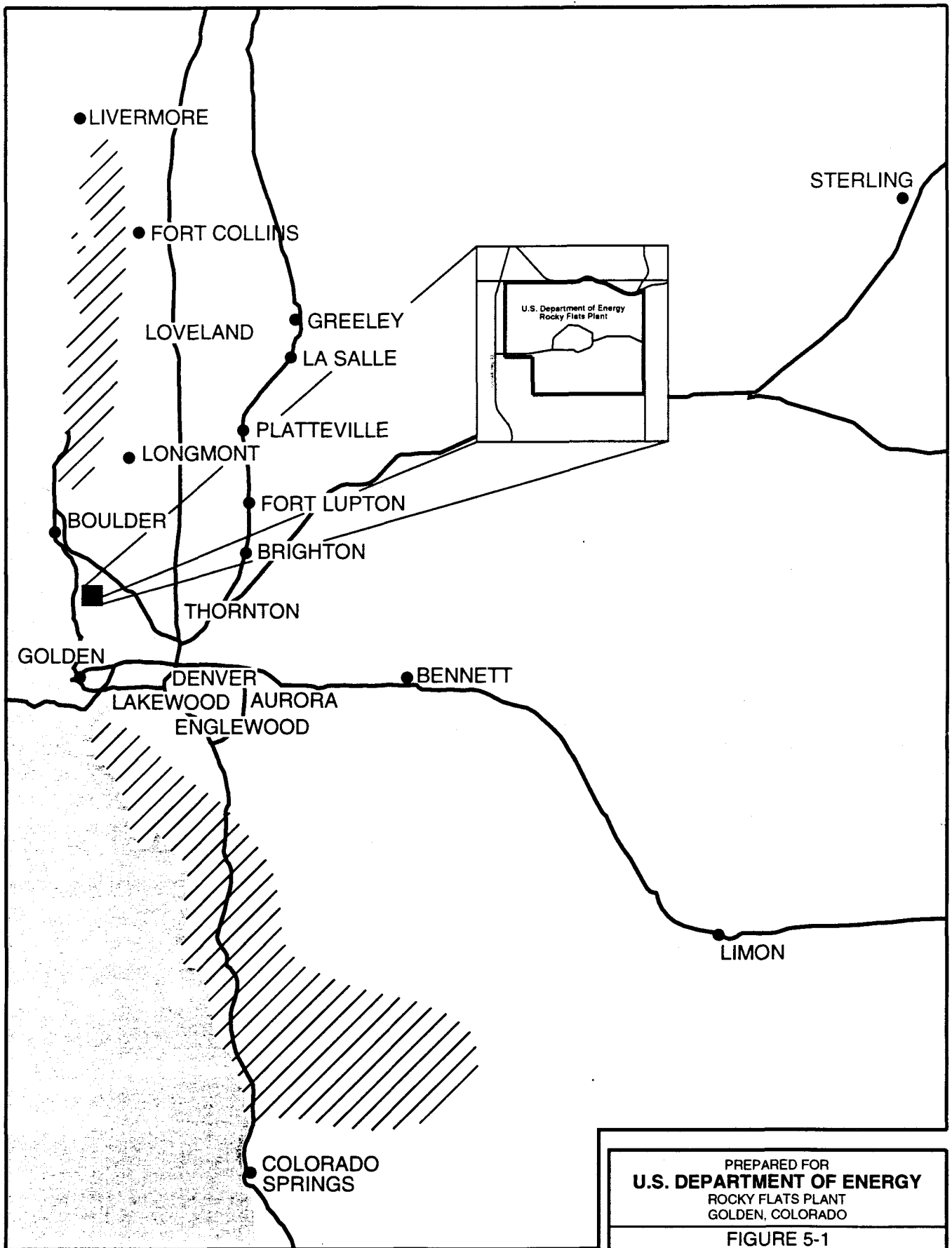
Eight eligible sampling areas have been identified and the sites visited along a belt east of the Front Range of Colorado from approximately Fort Collins to Colorado Springs. Besides meeting the location criteria, the eligible areas are owned by public agencies that have preliminarily approved access to the properties. The task of identifying sampling locations is ongoing at the time of publication of this draft work plan. The cross-hatch in Figure 5-1 illustrates the region that has the potential of satisfying the eligible location criteria. Final sampling locations within each selected sampling area will be dependent on the following:

- Final permission to access the sampling areas.
- Random selection of samples in each area.
- Professional judgment to ensure the sample locations are in undisturbed soils or least disturbed soils. If the site has been physically disturbed, another location will be selected and the procedure repeated.

5.1.2 Sampling Method

Surface soil sample points will be located in accordance with sampling plot layout procedures in GT.08 Surface Soil Sampling. After samples are collected within a sampling plot, the southwest corner of the plot will be surveyed using a global positioning system (GPS) method or standard land surveying techniques if GPS surveying cannot be performed. The GPS surveying procedure is outlined in GT.27, GT.28, and GT.29. The land surveying procedure is outlined in GT.17. Sample location will be sketched on a field map before leaving the field.

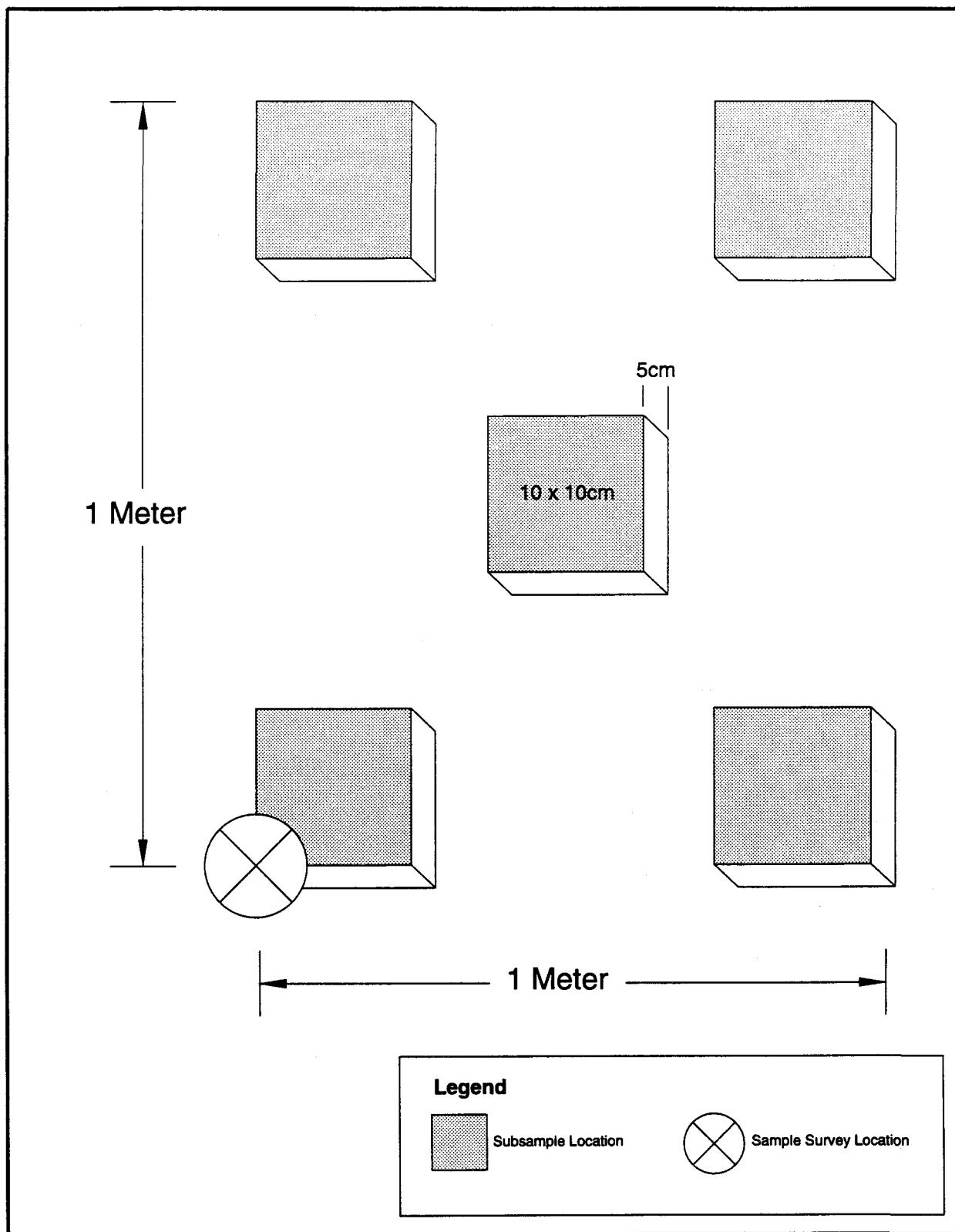
Five 2,500 cubic centimeter (cm³) [150 cubic inches (in³)] samples will be collected from a one-meter-square (m²) [10.76-foot-square (ft²)] area and composited following the RF soil sampling method (EG&G EMD OP GT.08). The RF method (Figure 5-2) employs a 10 by 10 by 5 cm (3.9 by 3.9 by two in) deep jig driven into the soil. Soil samples are removed from the interior of the jig with a stainless steel scoop and placed in a stainless steel pan. Five samples are collected by this method from within a one-meter-square template, one from each interior corner, and one from the center of the template. These five samples are first sieved through a 10-mesh metal sieve, placed in a stainless steel bowl, and mixed. A composited sample is placed into a sample container which has been labeled according to procedure FO.13, Containerization, Preserving, Handling, and Shipping of Soil and Water Samples. Sample containerization and holding time requirements are summarized in Table 5-5.



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FIGURE 5-1

REMOTE SAMPLING REGION
FOR FALLOUT RADIONUCLIDES



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FIGURE 5-2
 ROCKY FLATS METHOD FOR
 SOIL SAMPLING LOCATION
 AND SPACING

TABLE 5-5

SAMPLE CONTAINERS AND HOLDING TIMES FOR SOIL SAMPLES

| PARAMETER | CONTAINER | HOLDING TIME (DAYS) |
|--|--|---|
| TAL metals plus Cs, Li, Mo, Sn, Sr | 1 x 250 ml wide-mouth glass jar | 180 ¹ |
| TCL semivolatiles, pesticides, and PCBs | 1 x 250 ml wide-mouth Teflon-lined jar | 7 until extraction, 40 after extraction |
| Fallout and naturally occurring radionuclides | 1 x 1 l wide-mouth glass jar | 180 |
| TOC, anions, pH, specific conductance and oil and grease | 1 x 250 ml wide-mouth glass jar | 28 |
| Bulk density and particle size distribution | 1 gallon plastic jug | None |

¹ Holding time for mercury is 28 days

This process is described in FO.09. The sieve, jig, trowel, and pan will then be decontaminated prior to collecting the next sample by following procedure FO.3, General Equipment Decontamination. Field documents will be completed in accordance with FO.02 and field data will be managed per procedure FO.14, Field Data Management. Samples will be analyzed for the analytes identified in Table 5-2.

5.2 METALS AND ORGANIC GROUPS SURFACE SOIL SAMPLING

This section presents the field sampling plan for metals (including U and Ra) and organic compounds. This section includes the following elements:

- Selection of sampling locations
- Sampling method.

5.2.1 Selection of Sampling Locations

This sampling activity was designed to characterize the background concentrations in surface soil for the following:

- TAL metals and Cs, Li, Mo, Sr, and Sn
- $^{233/234}\text{U}$, ^{235}U , ^{238}U , ^{226}Ra , and ^{228}Ra .
- Organic compounds including base-neutral extractable semivolatile compounds, pesticides, and PCB compounds.

As discussed in Section 4.3, the EDA indicates that the Rock Creek data set is located in a background area with respect to these analytes and that the concentrations are within published values (notwithstanding variability with respect to non-point-source pollution). Therefore, this sampling effort is intended to augment the Rock Creek data set for those analytes. Additionally, soil data collected for this activity will include other soil parameters including ammonia, nitrate/nitrite, oil and grease, specific conductance, carbonate, pH, total organic carbon, particle size, and bulk soil density. These other surface soil parameters are intended to be used for modeling and water quality parameters consistent with data collected for the Rock Creek data set and other OU soil sampling efforts.

Based on the conceptual model and the EDA, the identification of potential sampling locations are conditional to the following factors:

- Soil type and geologic parent material
- Land use
- Land access.

Undisturbed areas north of RFP in the selected sampling area in Boulder County that are representative of soils and parent materials similar to those found at RFP have been chosen for sampling. Preliminary approval for access has been indicated by the Boulder County Open Space Department. Although the EDA indicates that metals and uranium isotopes at RFP are not significantly dependent on soil type in the surface soil, this sampling activity will utilize a stratified random sampling design to be conservative in its approach. Boulder County soils were not mapped according to the same soil map-unit design as the RFP site soils. However, the geologic map-units and landforms in the selected area in Boulder County are similar to RFP geologic map-units and landforms. Since there is a correlation between soil map-units at the subgroup level and geologic map-units and landforms at RFP, this same correlation should exist in the selected sampling area in Boulder County. Accordingly, the metals and organic groups sampling activity will be stratified according to geologic map-units and landforms in the selected sampling area north of RFP.

Figure 5-3 shows the location of the proposed sampling sites. The samples will be analyzed for the analytes listed on Table 5-3. Final sampling locations will be dependent on the following:

- Final permission to access individual sample sites.
- Professional judgment to ensure the sample locations are in undisturbed soils. If the site has been physically disturbed, another location will be randomly selected in the same soil type and geology, and the procedure repeated.

5.2.2 Sampling Method

The sampling methodology, surveying sample locations, equipment decontamination, sample handling, and documentation requirements that will be employed are similar to those described in Section 5.1.2.

5.3 SOIL PROFILE SAMPLING

This section presents the field sampling plan for soil profile sampling. This section includes the following elements:

- Selection of sampling locations
- Sampling method.

5.3.1 Selection of Sampling Locations

The purpose of the soil profile sampling is to collect baseline soils profile data in undisturbed or least disturbed soils. The objectives of soil profile sampling are:

- to provide data to assess the distribution of actinides with depth in soils west of the RFP industrial area and upwind from the former storage site (903 Pad)
- to provide data regarding selected physicochemical attributes and pedological processes that may govern the fate and transport of contaminants in soils upwind and upstream from RFP.

The soil pits will be excavated in undisturbed or least disturbed sites. Approximate sampling locations have been selected in the northwest buffer zone to select areas that have minimum potential effects from contaminants spread east and southeast by prevailing winds from the 903 Pad and the industrial area and by surface or groundwater flow from RFP contaminant sources.

The sampling design will be based on the catena concept. A catena is a group of geographically associated soils having properties related to the gradient of a slope as well as to the position of the soil on the slope (Soil Survey Staff, 1985). Soils across a catena influence each other in their development, especially on hilly terrain where water movement interconnects the soils as at RFP (Litaor, 1992). To address the differing soil properties along a catena, the sampling plan will include the sampling of soil pits located on the pediment surface, the upper slope, midslope, and toeslope of portions of the Rock Creek drainage (Figure 5-4). Three catenas will be located across sections of Rock Creek in the northwest buffer zone. Approximate locations are shown in Figure 5-5. The final location of the soil pits will be established in the field using aerial photographs, soil and topographic maps, and professional judgment.

Pediment Surface X

Upper-Slope X

Mid-Slope X

Toe Slope X

PREPARED FOR
U.S. DEPARTMENT OF ENERGY
ROCKY FLATS PLANT
GOLDEN, COLORADO

FIGURE 5-4
CATENA SAMPLING DESIGN FOR
SOIL PROFILES IN ROCK
CREEK REGION

5.3.2 Sampling Method

Sampling the soil profiles for characterization of radionuclide content and distribution involves the following special considerations:

- The potential for cross-contamination due to the introduction of surface materials into subsurface horizons
- The collection of sufficient material for representative actinide activities and other soil parameters
- The selection of a realistic sampling design that considers the high cost of actinide analyses and provides sufficient information regarding the vertical distribution of actinides in the soil profile.

In light of these considerations, a special sampling method will be employed as outlined in EG&G EMD OP GT.07, Logging and Sampling of Test Pits, Trenches, and Construction Excavations. This method involves digging a pit, three to five m (9.8 to 16.4 ft) long, one m (3.3 ft) wide, and one m (3.3 ft) deep. The vegetation, at the surface of the pit wall selected for sampling, will be clipped close to the ground and discarded. The surface of the selected wall will then be thoroughly scraped with a stainless-steel spade to reduce the possibility of cross-contamination. Ten soil samples will be collected per pit according to the following depth intervals: zero to 3, 3 to 6, 6 to 9, 9 to 12, 12 to 18, 18 to 24, 24 to 36, 36 to 48, 48 to 72, and 72 to 96 cm (zero to 1.2, 1.2 to 2.4, 2.4 to 3.5, 3.5 to 4.7, 4.7 to 7.1, 7.1 to 9.4, 9.4 to 14.2, 14.2 to 18.9, 18.9 to 28.3, 28.3 to 37.8 in). A bottom-to-top sampling sequence will be adopted to reduce further the risk of cross-contamination. Each soil sample will be collected from within a horizontal cavity dug into the trench face at a selected depth. An exception to the three cm depth intervals will be made for near-surface samples [zero to 12 cm (0 to 4.7 in)], where the soil may be too friable to permit discrete sampling. To sample the top section of the profile, the sampling will begin at ground level using a knife and spatula to cut an area approximately 25 cm (9.8 in) long, 20 cm (7.9 in) wide, and three cm (9.8 in) deep. The entire soil mass in this area will be collected including roots and partially decomposed organic material. Sampling will continue in this manner for intervals as much as 12 cm (4.7 in) deep.

Sampling for selected physical and chemical parameters will be conducted by genetic horizons rather than by the incremental depth procedure. The soils will be described and classified according to guidelines established by the Soil Survey Staff (1984, 1985, 1992). The samples will be analyzed as specified in Table 5-4.

All samples will be containerized and labeled according to procedure FO.13, Containerization, Preserving, Handling, and Shipping of Soil and Water Samples. Sample containerization and holding-time requirements are summarized in Table 5-5. This process is described in FO.09. The spatula and knife will then be decontaminated prior to collecting the next sample by following procedure FO.03, General Equipment Decontamination. Field documents will be completed in accordance with FO.02 and field data will be managed per procedure FO.14, Field Data Management. The backhoe used for excavation will be decontaminated between sites using procedure FO.04, Heavy Equipment Decontamination. However, because the sites are in background areas, decontamination water will be placed on the ground surface.

5.4 FIELD QUALITY CONTROL

During the BSCP field investigation, equipment rinsate blanks and field duplicate quality control (QC) samples will be collected in accordance with the RFP ER Program. The frequency for the field QC samples is specified in Table 5-6. These samples will be reviewed to evaluate the quality of the sampling program and to assess sample homogeneity.

Equipment rinsate blanks are used to monitor for sample cross-contamination and the effectiveness of the decontamination process. The blanks are collected by rinsing decontaminated sampling equipment with distilled/deionized water, placing it in the appropriate container, and preserving as required.

For soil samples, it is necessary to split the homogenized sample into two, duplicate portions using the same technique. The data from the sample and duplicate will provide a measure of the sampling precision and sample homogeneity, i.e. the amount of error in the data attributed to sampling technique or to variability in the analyte concentration in the medium being sampled.

Precision of the field duplicates is quantified by calculating the relative percent difference (RPD). The RPD is the quotient of the difference between the duplicate analytical results and the average of those results for the given analyte expressed as a percentage.

TABLE 5-6

FIELD QC SAMPLE FREQUENCY

| SAMPLE TYPE | PARAMETER | TOTAL SURFACE SAMPLES | QC SAMPLE FREQUENCY | TOTAL NUMBER OF SAMPLES AND QC SAMPLES |
|------------------|---|-----------------------|---------------------|--|
| Duplicates | TCL semivolatiles, pesticides, and PCBs | 20 | 1/20 | 21 |
| | Metals plus Cs, Li, Mo, Sn, Sr, $^{233/234}\text{U}$, ^{235}U , ^{226}Ra , and ^{228}Ra | 20 | 1/20 | 21 |
| | TOC, anions, pH, specific, specific conductance, and oil and grease | 20 | 1/20 | 21 |
| | Fallout Radionuclides | 50 | 1/20 | 53 |
| | Bulk density and particle size distribution | 20 | 1/20 | 21 |
| Equipment Blanks | TCL semivolatiles, pesticides, and PCBs | 20 | 1/20 | 21 |
| | Metals plus Cs, Li, Mo, Sn, Sr, $^{233/234}\text{U}$, ^{235}U , ^{226}Ra , and ^{228}Ra | 20 | 1/20 | 21 |
| | TOC, anions, pH, specific, specific conductance, and oil and grease | 20 | 1/20 | 21 |
| | Fallout Radionuclides | 50 | 1/20 | 53 |

1/20 = One QC sample per twenty samples collected.



6.0 DATA INTERPRETATION AND REPORTING

This section describes the approach to data interpretation and reporting. The approach to reporting is followed by a more detailed description of the statistical methods to be used to interpret and characterize background soil chemistry.

6.1 OVERALL APPROACH

Because of the demand for a timely completion of the background surface soils characterization, a draft report of these efforts, the Phase I Report, will be expedited. The results of the soil profile sampling activity will be reported later in the Phase II Report. For consistency, the reports will follow the logic and structure of the Background Geochemical Characterization Report (EG&G, 1993a), where applicable.

6.2 STATISTICAL METHODOLOGIES

This section describes the statistical methods to be used to characterize the background soil chemistry at RFP, including preliminary data analysis and evaluation of populations. Figure 6-1 illustrates the methodology for computing background statistics.

6.2.1 Preliminary Data Analysis

Available chemical data will be carefully reviewed in a multi-step process to establish a reliable set of data upon which conclusions can be drawn, and to identify recurring sampling or analytical problems that can be corrected in the future. Chemical data will be validated upon receipt from the analytical laboratory. The validation criteria and a definition of validation codes is provided in Section 7.3.8. These data and validated results will be stored in the RFEDS for later retrieval and use. After the validation background data have been retrieved from RFEDS, they will undergo evaluation of data usability which includes a review and interpretation of field quality control data and assessment of DQO achievement. Section 7.0 discusses data validation methods and procedures for assessing data usability.



Preliminary data evaluation will follow procedures for:

- Treatment of duplicates
- Treatment of non-detects
- Evaluation of data distribution
- Outlier detection.

The treatment of data that will be employed in this study, including criteria for characterizing data as a non-detected (ND) value and for data cleanup after a RFEDS download, are discussed in Appendix D.

6.2.1.1 Treatment of Duplicates

Sample duplicates and analytical replicates will be averaged for all analytes prior to estimating univariate statistics (Figure 6-1). If a detected and non-detected (ND) value comprise a duplicate pair, one half of the reported detection limit of the ND value will be averaged with the detected concentration. The resulting averaged value will be evaluated as a detected observation. Statistical methods will be evaluated for their sensitivity to this averaging method. Appendix D provides guidance on treatment of duplicate samples, data file consistency checks, and data cleanup exercises.

6.2.1.2 Treatment of Non-detects

Three general techniques can be employed for the replacement of NDs in a data set: simple substitution, probability plotting, and maximum likelihood estimators (MLEs). Three substitution techniques are commonly used to replace NDs: replacement with one-half the detection limit, replacement with zero, and replacement with the detection limit. Probability plotting methods are described in detail in Helsel and Cohn (1988). A common MLE is described by Cohen (1961) and Sanford et al. (1993).

Numerous studies, including Sanford et al. (1993), Gilliom and Helsel (1986), Helsel and Gilliom (1986), Helsel and Cohn (1988), Newman and Dixon (1990), Newman et al. (1989), Travis and Land (1990), and Lambert et al. (1991), generally consider simple substitution methods the least robust technique of ND substitution when descriptive statistics are required from a data set. However, this study will evaluate the suitability of each replacement method in the data analysis process. A discussion of the effects of these replacement techniques on statistical analysis results will be provided.

As illustrated in Figure 6-1, 80-percent NDs have been specified as the maximum percentage of NDs in a data set for utilizing replacement techniques. This criterion follows general guidelines provided by EPA (1992), Sanford et al. (1993), and Helsel and Cohn (1988). Maximum concentration, frequency of detection, and nonparametric tolerance limits will be reported for analytes with greater than 80-percent NDs.

6.2.1.3 Evaluation of Data Distribution

The data distribution of every analyte with less than 80-percent NDs will be evaluated to facilitate outlier detection and to prepare for later statistical procedures (Figure 6-1). Assessing the normality of the data set will be done visually with probability plots, stem-and-leaf diagrams, and box-and-whisker plots. Also, statistical tests of the hypothesis that data are from a normal distribution will be applied. These tests are the Shapiro-Wilk statistic (Shapiro and Wilk, 1965) and the Lilliefors test (Lilliefors, 1967). If the resulting plots, descriptive statistics and test statistics indicate that the data may not be normally distributed, the data will be log-transformed. The distribution of the transformed data will be evaluated in the same manner. The distribution that best fits the data will be used in subsequent outlier evaluation and statistical tests. Where data do not exhibit a normal or lognormal distribution, nonparametric procedures will be employed to compare sample populations.

6.2.1.4 Outlier Detection

An outlier is an extreme observation that does not conform to the pattern established by other observations and is unlikely to be a valid member of the population of interest. An outlier may be the result of an incorrectly read, recorded, or transcribed measurement, an incorrect calculation, an error in documentation (field or laboratory), or an actual environmental condition.

To evaluate the presence of outliers, the following procedure will be applied:

- The data, or logtransform data will be plotted on normal probability plots or box plots to identify extreme values.

- The single outlier test by Dixon (1953) or ASTM (1975) and described in the RCRA guidance document (EPA, 1989b) will be applied. Multiple outlier testing will follow Rosner (1975).
- The identified outlier will be evaluated with respect to the historical data trend and laboratory conditions such as matrix interference in an attempt to identify why the datum is aberrant.
- A decision will be made on how to treat the outlier. If the outlier resulted from a correctable error, the value will be changed, and the correct value will be included in the data set. If an error cannot be identified, the datum may be excluded from subsequent statistical analysis in the professional judgment of the statistician or geochemist. However, if one or more data points are excluded, the rationale for the exclusion will be discussed in the text of the report.

6.2.2 Evaluation of Populations

This subsection presents the approach and statistical methods that will be used to establish appropriate populations for background soil chemistry results.

The following statistical definitions are in used in this section.

- Observation is a measurement on the smallest sampling unit. One chemical analysis or set of analyses is an observation. Although this observation is based on a soil sample, a soil sample is not a statistical term and should not be confused with a statistical sample.
- Sample is a small subset of the population taken to represent the larger population.
- Population is a well-defined set of all possible observations.
- Subpopulation is a well-defined subset of the population.
- Multivariate is an adjective indicating that there is more than one dependent variable (analytes in the statistical models).
- Univariate is an adjective indicating that there is only one dependent variable.

One of the most powerful statistical procedures to test the hypothesis that several population means are equal is analysis of variance (ANOVA). Parametric and nonparametric ANOVA will be used to evaluate the effect of the different soil types on the population for each analyte. For parametric ANOVA to be applicable, the assumptions of normality and equality of variance must be met. That is, populations from which samples are randomly sampled must not only be normal but must have equal variances. To assess the "homogeneity of variance," Bartlett's test or Levene's test, as described by Snedecor and Cochran (1980), will be employed.

Nonparametric ANOVA will be performed if the assumptions of normality or homogeneity of variance are violated. A nonparametric ANOVA evaluates differences in the mean rankings of the data (rather than the raw data or transformations of the raw data) for subsets of the data defined by levels of a classification factor. The nonparametric test used will be the Wilcoxon rank-sum test for a comparison of two levels and the Kruskal-Wallis test, an extension of the Wilcoxon rank-sum test, for comparison of more than two soil types. A description of these nonparametric techniques can be found in Gilbert (1987).

Tables 5-2 and 5-3 list the analytes sampled as part of the background surface soil program. Sources of variability between soil types will be identified for the metals. In general, where significant differences are identified in soil types, separate tables of summary statistics will be reported for each new group. For fallout radionuclides, the data collected at remote sites will be compared to the Rock Creek data set following the same procedure (without regard to soil type) as depicted in Figure 6-1.

6.3 CALCULATION OF DESCRIPTIVE STATISTICS

Following the evaluation of analyte populations (Figure 6-1), the following procedures will be applied to calculate descriptive statistics:

- The maximum and minimum concentrations will be identified
- The percentage of NDs will be calculated
- The mean and standard deviation will be estimated

- Parametric tolerance limits with 99-percent confidence and 99 percent of the background distribution will be computed if the sample distribution is normal or lognormal
- Nonparametric tolerance limits will be computed if the sample distribution is neither normal or lognormal.

The information generated through application of these procedures will be reported in summary statistics tables for each analyte. A comparison of descriptive statistics by replacement technique will also be presented. Information regarding differences between data sets (i.e., soil types for metals) will also be reported and tabulated, if necessary.



7.0 QUALITY ASSURANCE ADDENDUM

This section consists of the Quality Assurance Addendum (QAA) for the BSCP. This QAA is a supplement to, and must be used in conjunction with, the *Rocky Flats Plant Site-Wide Quality Assurance Project Plan for CERCLA Remedial Investigation/Feasibility Studies and RCRA Facility Investigations/Corrective Measures Studies Activities* (QAPjP), (EG&G, 1990). The QAA establishes the site-specific Quality Assurance (QA) controls applicable to the investigation activities described in the BSCP work plan.

As discussed in previous sections, the BSCP work plan establishes a program for the characterization of background soil chemistry for RFP. Background soil data will provide a baseline against which RFI/RI soils data may be compared for identifying contamination at RFP OUs. The BSCP work plan was prepared using *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA* (EPA, 1988) as a reference for the document format.

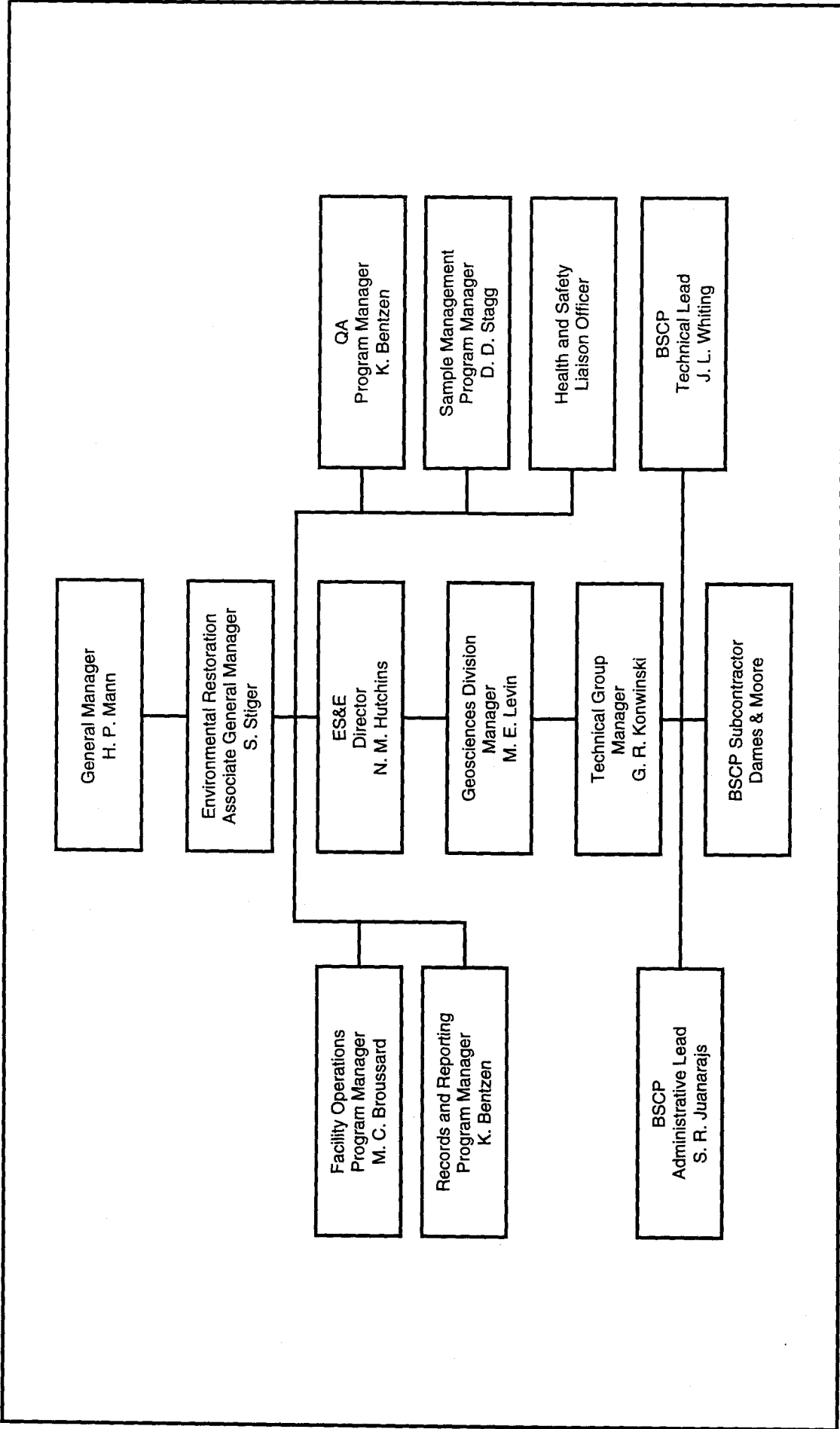
For consistency with the QAPjP, this QAA is organized by the same 19 QA elements contained therein.

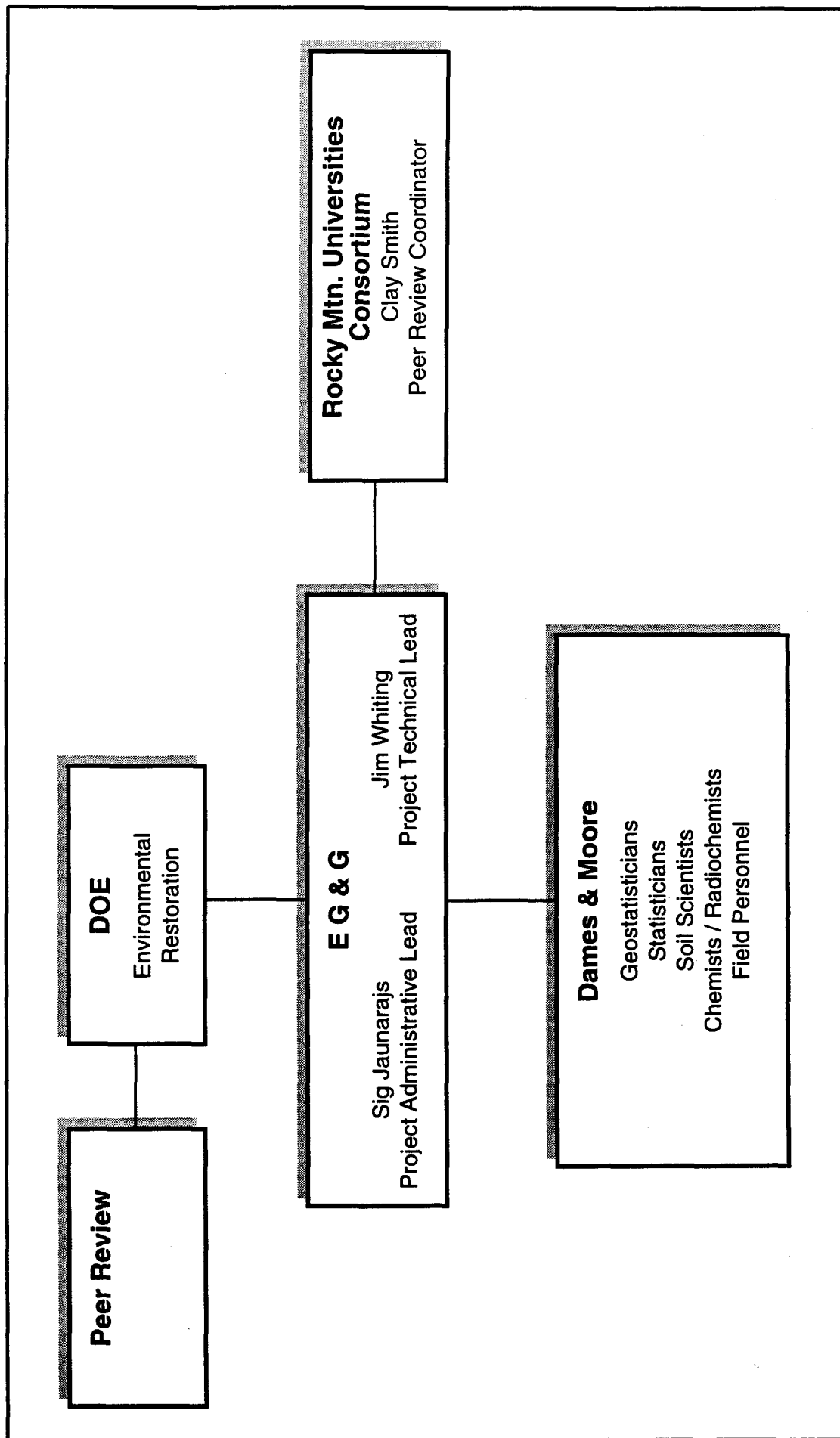
7.1 ORGANIZATION AND RESPONSIBILITIES

The overall organization of EG&G, EMD, and divisions involved in ER Program activities are shown in Figures 1-1, 1-2, and 1-3 of Section 1.0 of the QAPjP. Individual responsibilities are also described in Section 1.0 of the QAPjP. The Project Management structure for the BSCP is illustrated in Figure 7-1. The BSCP project organization is illustrated in Figure 7-2. Project-specific roles from EG&G and the subcontractor are discussed in the following paragraphs.

The EG&G BSCP Project Manager and designated technical staff are responsible for the management and technical direction of the project. Input to this work plan has been provided by EG&G and input to the subsequent project documents is also anticipated.

Contractor responsibilities for the BSCP include preparation of all project deliverables, implementation of the BSCP work plan, and providing technical support as requested by EG&G Project Management.





7.2 QUALITY ASSURANCE PROGRAM

The QAPjP was written to address QA controls and requirements for implementing IAG-related activities. The content of the QAPjP was driven by DOE Order 5400.1, RFP SOP 5700.6B, and the IAG. DOE 5400.1 and SOP 5700.6B both require a QA program to be implemented based on American Society of Mechanical Engineers (ASME) NQA-1, *Quality Assurance Requirements for Nuclear Facilities* (ASME, 1989). The IAG specifies development of a QAPjP in accordance with EPA QAMS-005/80, *Interim Guidelines and Specifications for Preparing Quality Assurance Project Plans* (EPA, 1980). The 18-element format of NQA-1 was selected as the basis for both the QAPjP and subsequent QAAs with the applicable elements of QAMS-005/80 incorporated where appropriate. Figure 2-1 of the QAPjP illustrates where the 16 QA elements of QAMS-005/80 are integrated into the QAPjP and also into this QAA. Section 2.0 of the QAPjP also identifies other DOE orders and QA requirements documents which the QAPjP and this QAA respond to.

The controls and requirements addressed in the QAPjP are applicable to BSCP activities, unless specified otherwise in this QAA. Where sitewide actions are applicable to BSCP activities, the applicable section of the QAPjP is referenced in this QAA. This QAA addresses additional and site-specific QA controls and requirements that are applicable to BSCP activities, but may not have been addressed on a sitewide basis in the QAPjP. Many of the QA requirements specific to BSCP are addressed in the BSCP work plan and are referenced in this QAA.

7.2.1 Training

This section addresses the project-specific training requirements and QA reports to management. The minimum personnel qualification and training requirements that are applicable to EG&G and subcontractor staff for RFP ER Program activities are addressed in Section 2.0 of the QAPjP. All EG&G and subcontractor staff working on BSCP investigations will be trained in the specific EMD OPs that are applicable to their assigned tasks. Project Managers will be trained by the EMD and are responsible for training subcontractor staff according to EMD Administrative Procedure 3-21000-ADM-02.01, Personnel Training, using EG&G-furnished lesson plans. All personnel training will be documented according to procedure 3-21000-ADM-02.01.

For the BSCP, EG&G EMD and subcontractor personnel will be trained in the BSCP work plan, the BSCP Health and Safety Plan (HASp) (in preparation), and the EMD OPs referenced in Table 5-1. A training matrix has been prepared by the EG&G BSCP Project Manager to identify and document the training requirements specific to the BSCP.

7.2.2 Quality Assurance Reports to Management

A QA summary report will be prepared annually or at the conclusion of these activities (whichever is more frequent) by the EMD Quality Assurance Project Manager (QAPM) or designee. This report will include a summary of field operations and laboratory inspections, surveillance, and audits and a report on data verification/validation results.

7.3 DESIGN CONTROL AND CONTROL OF SCIENTIFIC INVESTIGATIONS

This section documents the following with regard to QA:

- Design control
- DQOs
- Field sampling program and sampling procedures
- Analytical procedures
- Equipment decontamination
- Quality control
- Quality assurance monitoring
- Data reduction, validation, and reporting.

7.3.1 Design Control

The BSCP work plan describes the investigation activities that will be implemented during the program. Section 1.2 identifies the purpose and objectives of the investigations; Sections 5.1, 5.2, and 5.3 specifies the sampling, analysis, and data generation requirements as well as identifying applicable EMD OPs that will provide controls for the investigations. This section identifies the applicable QA requirements, analytical procedures, and control mechanisms for the project. As such, the BSCP work plan is considered the investigation control plan. After the BSCP work plan has been approved by EG&G and DOE, any changes or revisions to the work plan will also be reviewed and approved.

7.3.2 Data Quality Objectives

The DQOs for the BSCP investigations are presented in Section 4.0. The DQOs for BSCP were established in accordance with the three-stage process described in EPA/540/G-87/003 (OSWER Directive 9335.0-7B), *Data Quality Objectives for Remedial Response Activities - Development*

Process (EPA, 1987), the *Interim Final Guidance for Planning for Data Collection in Support of Environmental Decision Making Using the Data Quality Objectives Process*, EPA QA/G-4, (EPA, 1994), and Appendix A of the QAPjP. Identification of data quality needs includes defining specific investigation objectives, identifying data uses, and selecting the types of samples and data that need to be collected. The primary objectives for the BSCP investigation, specific data needs, data uses, sampling and analysis activities, and DQOs were identified in Section 4.0.

7.3.2.1 Precision, Accuracy, Representativeness, Completeness, and Comparability (PARCC) Parameters

This section discusses PARCC parameters and analytical data requirements.

Data quality is typically measured in terms of PARCC parameters. Precision, accuracy, and completeness are quantitative measures of data quality, while representativeness and comparability are qualitative statements that express the degree to which sample data represent actual conditions and describe the confidence of one data set to another. These parameters are defined in Appendix A of the QAPjP and summarized as follows.

- Precision is a measure of the variability in repeated measurements of the same sample compared to the average value for all samples. Precision objectives for the analytes listed in Table 7-1 are as prescribed in the method.
- Accuracy measures the bias or source of error in a group of measurements; bias is an indication of the systematic error within an analytical technique. Accuracy objectives for the analytical data collected for the BSCP will be evaluated according to the control limits specified in the referenced analytical method and/or in data validation guidelines.
- Representativeness expresses the degree to which sample data accurately and precisely represent the characteristics of a particular site or population, parameter variations at a sampling point, or an environmental condition. Representativeness is also a qualitative parameter related to the proper design of the sampling and analysis program. As described in the DQO section (Section 4.0) and outlined in the FSP (Section 5.1, 5.2, and 5.3), sample location selection has been designed to represent environmental conditions applicable to each analyte group which can be found in the affected areas at RFP. Section 4.3 describes the rationale used to promote representativeness in samples collected for the BSCP.

TABLE 7-1

**ANALYTICAL METHODS AND DETECTION LIMITS
FOR BSCP SOIL AND SOIL PROFILE SAMPLES**

| ANALYTE | METHOD | REQUIRED DETECTION LIMITS |
|--|-----------------------|--|
| Target Analyte List - Metals (all units in mg/kg) | | |
| Aluminum | Table 42 ^a | 40 |
| Antimony | Table 42 ^a | 12 |
| Arsenic (GFAA) | Table 42 ^a | 2 |
| Barium | Table 42 ^a | 40 |
| Beryllium | Table 42 ^a | 1.0 |
| Cadmium | Table 42 ^a | 1.0 |
| Calcium | Table 42 ^a | 2000 |
| Chromium | Table 42 ^a | 2.0 |
| Cobalt | Table 42 ^a | 10 |
| Copper | Table 42 ^a | 5.0 |
| Iron | Table 42 ^a | 20 |
| Lead (GFAA) | Table 42 ^a | 1.0 |
| Magnesium | Table 42 ^a | 2000 |
| Manganese | Table 42 ^a | 3.0 |
| Mercury (CVAA) | Table 42 ^a | 0.2 |
| Nickel | Table 42 ^a | 8.0 |
| Potassium | Table 42 ^a | 2000 |
| Selenium (GFAA) | Table 42 ^a | 1.0 |
| Silver | Table 42 ^a | 2.0 |
| Sodium | Table 42 ^a | 2000 |
| Thallium (GFAA) | Table 42 ^a | 2.0 |
| Vanadium | Table 42 ^a | 10 |
| Zinc | Table 42 ^a | 4.0 |
| Cesium | Table 43 ^a | 200 |

TABLE 7-1 (CONTINUED)

**ANALYTICAL METHODS AND DETECTION LIMITS
FOR BSCP SOIL AND SOIL PROFILE SAMPLES**

| ANALYTE | METHOD | REQUIRED DETECTION LIMITS |
|--|-----------------------|--|
| Target Analyte List - Metals (all units in mg/kg) (Continued) | | |
| Lithium | Table 43 ^a | 20 |
| Molybdenum | Table 43 ^a | 40 |
| Tin | Table 43 ^a | 40 |
| Strontium | Table 43 ^a | 40 |
| Target Compound List - Semivolatiles (all units in $\mu\text{g/kg}$) | | |
| Phenol | Table 13 ^b | 330 |
| bis(2-Chloroethyl)ether | Table 13 ^b | 330 |
| 2-Chlorophenol | Table 13 ^b | 330 |
| 1,3-Dichlorobenzene | Table 13 ^b | 330 |
| 1,4-Dichlorobenzene | Table 13 ^b | 330 |
| Benzyl Alcohol | Table 13 ^b | 330 |
| 1,2-Dichlorobenzene | Table 13 ^b | 330 |
| 2-Methylphenol | Table 13 ^b | 330 |
| bis(2-Chloroisopropyl)ether | Table 13 ^b | 330 |
| 4-Methylphenol | Table 13 ^b | 330 |
| N-Nitroso-Dipropylamine | Table 13 ^b | 330 |
| Hexachloroethane | Table 13 ^b | 330 |
| Nitrobenzene | Table 13 ^b | 330 |
| Isophorone | Table 13 ^b | 330 |
| 2-Nitrophenol | Table 13 ^b | 330 |
| 2,4-Dimethylphenol | Table 13 ^b | 330 |
| Benzoic Acid | Table 13 ^b | 1600 |
| bis(2-Chloroethoxy)methane | Table 13 ^b | 330 |

TABLE 7-1 (CONTINUED)

**ANALYTICAL METHODS AND DETECTION LIMITS
FOR BSCP SOIL AND SOIL PROFILE SAMPLES**

| ANALYTE | METHOD | REQUIRED DETECTION LIMITS |
|--|-----------------------|---------------------------------|
| Target Compound List - Semivolatiles (all units in $\mu\text{g/kg}$) (Continued) | | |
| 2,4-Dichlorophenol | Table 13 ^b | 330 |
| 1,2,4-Trichlorobenzene | Table 13 ^b | 330 |
| Naphthalene | Table 13 ^b | 330 |
| 4-Chloroaniline | Table 13 ^b | 330 |
| Hexachlorobutadiene | Table 13 ^b | 330 |
| 4-Chloro-3-methylphenol | Table 13 ^b | 330 |
| 2-Methylnaphthalene | Table 13 ^b | 330 |
| Hexachlorocyclopentadiene | Table 13 ^b | 330 |
| 2,4,6-Trichlorophenol | Table 13 ^b | 330 |
| 2,4,5-Trichlorophenol | Table 13 ^b | 1600 |
| 2-Chloronaphthalene | Table 13 ^b | 330 |
| 2-Nitroaniline | Table 13 ^b | 1600 |
| Dimethylphthalate | Table 13 ^b | 330 |
| Acenaphthalate | Table 13 ^b | 330 |
| 2,6-Dinitrotoluene | Table 13 ^b | 330 |
| 3-Nitroaniline | Table 13 ^b | 1600 |
| Acenaphthene | Table 13 ^b | 330 |
| 2,4-Dinitrophenol | Table 13 ^b | 1600 |
| 4-Nitrophenol | Table 13 ^b | 1600 |
| Dibenzofuran | Table 13 ^b | 330 |
| 2,4-Dinitrotoluene | Table 13 ^b | 330 |
| Diethylphthalate | Table 13 ^b | 330 |
| 4-Chlorophenol Phenyl ether | Table 13 ^b | 330 |
| Fluorene | Table 13 ^b | 330 |

TABLE 7-1 (CONTINUED)

**ANALYTICAL METHODS AND DETECTION LIMITS
FOR BSCP SOIL AND SOIL PROFILE SAMPLES**

| ANALYTE | METHOD | REQUIRED DETECTION LIMITS |
|--|-----------------------|---------------------------------|
| Target Compound List - Semivolatiles (all units in $\mu\text{g/kg}$) (Continued) | | |
| 4-Nitroaniline | Table 13 ^b | 1600 |
| 4,6-Dinitro-2-methylphenol | Table 13 ^b | 1600 |
| N-nitrosodiphenylamine | Table 13 ^b | 330 |
| 4-Bromophenyl Phenyl ether | Table 13 ^b | 330 |
| Hexachlorobenzene | Table 13 ^b | 330 |
| Pentachlorophenol | Table 13 ^b | 1600 |
| Phenanthrene | Table 13 ^b | 330 |
| Anthracene | Table 13 ^b | 330 |
| Di-n-butylphthalate | Table 13 ^b | 330 |
| Fluoranthene | Table 13 ^b | 330 |
| Pyrene | Table 13 ^b | 330 |
| Butyl Benzylphthalate | Table 13 ^b | 330 |
| 3,3'-Dichlorobenzidine | Table 13 ^b | 660 |
| Benzo(a)anthracene | Table 13 ^b | 330 |
| Chrysene | Table 13 ^b | 330 |
| bis(2-ethylhexyl)phthalate | Table 13 ^b | 330 |
| Di-n-octyl Phthalate | Table 13 ^b | 330 |
| Benzo(b)fluoranthene | Table 13 ^b | 330 |
| Benzo(k)fluoranthene | Table 13 ^b | 330 |
| Benzo(a)pyrene | Table 13 ^b | 330 |
| Indeno(1,2,3-cd)pyrene | Table 13 ^b | 330 |
| Dibenz(a,h)anthracene | Table 13 ^b | 330 |
| Benzo(g,h,i)perylene | Table 13 ^b | 330 |

TABLE 7-1 (CONTINUED)

ANALYTICAL METHODS AND DETECTION LIMITS
FOR BSCP SOIL AND SOIL PROFILE SAMPLES

| ANALYTE | METHOD | REQUIRED DETECTION LIMITS |
|--|-----------------------|---------------------------------|
| Target Compound List - Pesticides/PCBs (all units in $\mu\text{g/kg}$) | | |
| alpha-BHC | Table 23 ^b | 8.0 |
| beta-BHC | Table 23 ^b | 8.0 |
| delta-BHC | Table 23 ^b | 8.0 |
| gamma-BHC (Lindane) | Table 23 ^b | 8.0 |
| Heptachlor | Table 23 ^b | 8.0 |
| Aldrin | Table 23 ^b | 8.0 |
| Heptachlor Epoxide | Table 23 ^b | 8.0 |
| Endosulfan I | Table 23 ^b | 8.0 |
| Dieldrin | Table 23 ^b | 16.0 |
| 4,4'-DDE | Table 23 ^b | 16.0 |
| Endrin | Table 23 ^b | 16.0 |
| Endosulfan II | Table 23 ^b | 16.0 |
| 4,4'-DDD | Table 23 ^b | 16.0 |
| Endosulfan Sulfate | Table 23 ^b | 16.0 |
| 4,4'-DDT | Table 23 ^b | 16.0 |
| Methoxychlor | Table 23 ^b | 80.0 |
| Endrin Ketone | Table 23 ^b | 16.0 |
| alpha-Chlordane | Table 23 ^b | 80.0 |
| gamma-Chlordane | Table 23 ^b | 80.0 |
| Toxephene | Table 23 ^b | 160.0 |
| AROCLOR-1016 | Table 23 ^b | 80.0 |
| AROCLOR-1221 | Table 23 ^b | 80.0 |
| AROCLOR-1232 | Table 23 ^b | 80.0 |
| AROCLOR-1242 | Table 23 ^b | 80.0 |

TABLE 7-1 (CONTINUED)

ANALYTICAL METHODS AND DETECTION LIMITS
FOR BSCP SOIL AND SOIL PROFILE SAMPLES

| ANALYTE | METHOD | REQUIRED DETECTION LIMITS |
|---|---|---------------------------------|
| Target Compound List - Pesticide/PCBs (all units in $\mu\text{g/kg}$) (Continued) | | |
| AROCLOR-1248 | Table 23 ^b | 80.0 |
| AROCLOR-1254 | Table 23 ^b | 160.0 |
| AROCLOR-1260 | Table 23 ^b | 160.0 |
| Fallout and Naturally Occurring Radionuclides¹ (all units in pCi/g) | | |
| Uranium-233/234 | e,f,g,h,i,l | 0.3 |
| Uranium-235/238 | e,f,g,h,i,l | 0.3 |
| Americium-241 | e,f,g,h,i,j,k,l | 0.02 |
| Plutonium-239/240 | e,f,g,h,i,j,k,l | 0.03 |
| Strontium-89/90 | e,f,g,h,i,l | 1 |
| Cesium-137 | e,f,g,h,i,l | 0.1 |
| Radium-226 | e,f,g,h,i,l | 0.5 |
| Radium-228 | e,f,g,h,i,l | 0.5 |
| Other Chemical Parameters²/Physical Properties³ (units as specified) | | |
| Ammonia | EPA 350 Series ^d | 0.05 ppm |
| Carbonate | EPA 310.1 ^d | 10 ppm |
| Nitrate/nitrite as N | EPA 353.1 or 353.2 ^d | 0.1 ppm |
| Total Organic Carbon | EPA 415.1 ^d or ASTM D4129-82 | 1 ppm |
| Oil and Grease | EPA 413.1 ^d or 413.2 | 5 ppm |
| Specific Conductance | EPA 120.1 ^d | 1 μS |
| Soil pH | EPA 9045 ^c | 0.1 pH units |

¹ Radiochemistry is performance based per GRRASP. The procedures used by the laboratory must be derived from one (or more) of the referenced methods.

² Methods modified to accommodate soil matrix; detection limits may vary.

³ Physical properties testing will be conducted by Iowa State University and will be consistent with previous investigations by Litaor (1993b).

TABLE 7-1 (CONCLUDED)

**ANALYTICAL METHODS AND DETECTION LIMITS
FOR BSCP SOIL AND SOIL PROFILE SAMPLES**

- ^a Per GRRASP: U.S. EPA Contract Laboratory Program Statement of Work for Inorganics Analysis, Multi-Media, Multi-Concentration, 7/88 (or latest revision).
- ^b Per GRRASP: U.S. EPA Contract Laboratory Program Statement of Work for Organics Analysis, Multi-Media, Multi-Concentration, 2/88 (or latest revision).
- ^c Methods are from "Test Methods for Evaluation of Solid Waste, Physical/Chemical Methods," (SW-846, 3rd Ed.), U.S. Environmental Protection Agency.
- ^d Methods for Chemical Analysis of Water and Wastes, EPA-600/4-79-02, March 1983.
- ^e U.S. Environmental Protection Agency, 1979, Radiochemical Analytical Procedures for Analysis of Environmental Samples, Report No. EMSL-LY-0539-1, Las Vegas, NV, U.S. Environmental Protection Agency.
- ^f U.S. Environmental Protection Agency, 1976. Interim Radiochemical Methodology for Drinking Water, Report No. EPA-600/4-75-008. Cincinnati U.S. Environmental Protection Agency.
- ^g Harley, J.H., ed., 1975, ASL Procedures Manual, HASL-300; Washington, D.C., U.S. Energy Research and Development Administration.
- ^h "Prescribed Procedures for Measurement of Radioactivity in Drinking Water," EPA-600/4-80-032, August 1980, Environmental Monitoring and Support Laboratory, Office of Research and Development, U.S. Environmental Protection Agency, Cincinnati, Ohio 45268.
- ⁱ "Methods for Determination of Radioactive Substances in Water and Fluvial Sediments," U.S.G.S. Book 5, Chapter A5, 1977.
- ^j "Acid Dissolution Method for the Analysis of Plutonium in Soil," EPA-600/7-79-081, March 1979, U.S. EPA Environmental Monitoring and Support Laboratory, Las Vegas, Nevada, 1979.
- ^k "Procedures for the Isolation of Alpha Spectrometrically Pure Plutonium, Uranium, and Americium," by E.H. Essington and B.J. Drennon, Los Alamos National Laboratory, a private communication.
- ^l U.S. EPA, 1987. "Eastern Environmental Radiation Facility Radiochemistry Procedures Manual," EPA-520/5-84-006.

- Completeness is defined as the percentage of measurements made that are judged to be valid. The target completeness for both field sampling and analytical data for the BSCP is 90 percent.
- Comparability is a qualitative parameter that expresses the confidence with which one data set can be compared with another. Comparability between historic surface soil data sets may be dependent on the sampling method used and the time between sampling periods. The RF method, which samples surface soils to a depth of five cm (two in), has been used at RFP since 1969 for determining Pu concentrations in soil, for gathering data for the ongoing environmental monitoring soil sampling program, and for RCRA/CERCLA investigations. This method was developed for the rocky surface in the vicinity of RFP and is considered a compromise between determining total Pu inventories in the soil and providing information for assessing human health risk through the inhalation pathway. Hence, it is concluded that the RF sampling method will meet the comparability goals for this project. To achieve comparability with surface soils data utilizing the RF and pit/trench methods, work will be performed in accordance with approved plans, using standard analytical protocols, and approved standard EMD OPs for data collection. Consistent units of measurement will be used for data reporting.

The objectives of precision and accuracy are dependent on the analyte of interest, the analytical method, and the QC that is applicable to the method. Table 7-1 defines the analytical methods and the required detection limits for the BSCP samples. Achievement of PARCC parameters will be assessed for BSCP measurement data, as described in the Evaluation of ERM Data for Usability in Final Reports; 2-G32-ER-ADM-08.02.

7.3.2.2 Analytical Data

EG&G has established requirements for analytical chemistry services for environmental samples collected in support of the RFP ER Program. These requirements are established in Parts A and B of the EG&G Rocky Flats GRRASP. The GRRASP requires analyses of EPA's TCL organics and TAL metals to be analyzed using EPA Contract Laboratory Program (CLP) methods and procedures. The GRRASP also requires analyses of all non-CLP and radiochemistry parameters to be modified such that the analyses parallel the QC requirements of CLP-type analyses. Therefore, all organic and inorganic laboratory analytical data should meet the QC needs equivalent to analytical level IV data. Table 7-1 identifies the analytical method, and the required detection limit for the BSCP samples.

Historical measures of precision and accuracy for TCL volatile and semi-volatile organics and TAL metals have been established for CLP analyses. These historical measures of precision and accuracy are referenced in Appendix B of the QAPjP and represent the objectives for TCL organics and TAL metals for the BSCP. Appendix B of the QAPjP also references the precision and accuracy measures for radionuclides that will be analyzed according to methods specified in Part B of the GRRASP. These measures represent the objectives that are applicable to the analysis of radionuclides for BSCP samples.

7.3.3 Field Sampling Program and Sampling Procedures

The field investigation program presented in the Field Sampling Plan (FSP) (Section 5.0) includes surface soil and soil profile sampling. The FSP includes descriptions of the two programs. The first, chemical characterization of surface soil material in undisturbed, unimpacted areas, is necessary to support RCRA/CERCLA decisions. Sampling will involve collecting the top five cm (two in) of soil. The second sampling effort, chemical and physical properties characterization of the upper one m (3.3 ft) of soil material for each of the major soil taxonomic groups at RFP, supports site-wide soils characterization studies. Soil profile investigations will be accomplished via pit/trench sampling activities. The specific sampling plan, including sampling locations, numbers of samples to be collected, and applicable EMD OPs is described in Sections 5.1, 5.2, and 5.3. The field operating and sampling procedures that will be used to control field sampling activities are identified on Table 5-1.

7.3.4 Analytical Procedures

The analytical program for the BSCP is discussed by sampling activity in Sections 5.1, 5.2, and 5.3. The analytes of interest and corresponding analytical methods, and the specified required detection/quantitation limits are identified in Table 7-1. The analytical methods prescribed are those that are specified in Parts A and B of the GRRASP. These methods are referenced in Section 3.0 of the QAPjP as well as detailed in Appendix B of the QAPjP.

7.3.5 Equipment Decontamination

Non-dedicated sampling equipment (i.e., sampling equipment that is used at more than one location) will be decontaminated between sampling locations in accordance with EMD OP FO.03, General Equipment Decontamination. Other equipment (e.g., heavy equipment) potentially contaminated during the pit/trench sampling activities will be decontaminated as specified in EMD OP FO.04, Heavy Equipment Decontamination.

7.3.6 Quality Control

To verify the quality of field sampling and laboratory analytical procedures, the collection, preparation, and analysis of QC samples are incorporated into the sampling and analytical programs.

7.3.6.1 Field Quality Control (QC) Samples

This section discusses field QC samples and laboratory QC procedures to support quality verification.

Field QC samples and collection frequencies for BSCP are discussed in Section 5.4 and identified in Table 5-6. A specific sampling schedule will be prepared by the sampling subcontractor for approval by the EG&G Laboratory Analysis Task Leader (Figure 7-1) prior to sampling. Equipment rinsate blanks, which are collected and analyzed to detect cross contamination of samples due to inadequate equipment decontamination, are considered acceptable (with no need for data qualification) if the concentration of analytes of interest is less than three times the required detection limit for each analyte as specified in Table 7-1. Field duplicate samples collected and analyzed to provide an indication of overall sampling and analytical precision will agree within 35 percent RPD calculated as follows:

$$\% \text{ RPD} = 100(C1 - C2)/(C1 + C2)/2$$

where:

- RPD = Relative percent difference.
- C1 = Concentration of analyte in the sample.
- C2 = Concentration of analyte in the duplicate.

7.3.6.2 Laboratory Quality Control Procedures

Laboratory QC procedures are used to provide measures of internal consistency of analytical and storage procedures. The laboratory contractor will submit written Standard Operating Procedures (SOPs) to the Laboratory Analysis Task Leader for approval. The inter-laboratory SOPs will be consistent with or equivalent to EPA-CLP QC procedures. The laboratory SOPs must cover the following areas in sufficient detail and reflect actual operating conditions in effect during analysis of BSCP samples:

- Sample receipt and log-in
- Sample storage and security
- Facility security
- Sample tracking (from receipt to sample disposition)
- References for sample analysis methods
- Data reduction, verification, and reporting
- Document control (including submitting documents to EG&G)
- Data package assembly (per Section III.A of the GRRASP)
- Qualifications of personnel
- Preparation of standards
- Equipment maintenance and calibration
- Instrumentation and equipment list (including purchase and installation dates, model number, manufacturer, and service contracts, if any)
- Instrument detection limits
- Acceptance criteria for non-CLP analyses
- Laboratory QC checks applicable to each analytical method.

Laboratory QC techniques to ensure consistency and validity of analytical results (including detecting potential laboratory contamination of samples) include using reagent blanks, field blanks, internal standard reference materials, laboratory replicate analysis, and field duplicates. The laboratory analysis contractor will follow the standard evaluation guidelines and QC procedures, including frequency of QC checks, that are applicable to the analytical method used

as specified in Parts A and B of the GRRASP and Section 3.0 of the QAPjP. All data packages will be forwarded to the Laboratory Analysis Task Leader or delegate (Figure 7-1) for review and verification.

7.3.7 Quality Assurance Monitoring

To ensure the overall quality of the BSCP activities discussed, field inspections, audits and surveillance may be conducted. If performed, the intervals will be determined by the importance and complexity of each activity. Intervals may also be based on the schedule contained in Section 8.0. Each of the field sampling activities described in Sections 5.1, 5.2, and 5.3 potentially will be monitored by an independent surveillance team at least once during the sampling process. EG&G will conduct audits of the laboratory contractor(s) as specified in the GRRASP, Parts A and B. The audits and surveillance, and activity Readiness Reviews are discussed further in the QAPjP.

7.3.8 Data Reduction, Validation, and Reporting

Reporting turnaround times, data reduction, data validation, and data reporting requirements are presented in the following subsections.

7.3.8.1 Data Reporting Turnaround Times

Reporting turnaround times for analytical data are as specified in Table 3-1 of Section 3.0 of the QAPjP.

7.3.8.2 Data Reduction

All field data will be recorded on field sampling data sheets and/or logbooks as specified in the appropriate EMD OP. Field data will be controlled according to EMD OP FO.02, Field Document Control. Reduction of laboratory measurements will be in accordance with the methods specified for each analytical method. Laboratory data will be compiled into sample data packages by the laboratory contractor. A sample data package will be developed for each sample delivery group or sample batch, with separate data packages for each type of analysis (e.g., a data package for organics, one for inorganics, and one for radionuclides). The sample data package will consist of a cover sheet/transmittal letter, a case narrative, data summary forms, and copies of the data checklists found in Attachments I in Parts A and B of the

GRRASP. The reduced data will be used in the data validation process to verify that the laboratory control and the overall system DQOs have been met.

7.3.8.3 Data Validation

Validation activities consist of reviewing and verifying field and laboratory data, and evaluating these verified data for data quality (i.e., comparison of reduced data to DQOs, where appropriate). The field and laboratory data validation activities and guidelines are described and referenced in Section 3.0 of the QAPjP. The process for validating the quality of the data is illustrated graphically in Figure 3-1 of Section 3.0 of the QAPjP, and is also included as part of the sample collection, chain-of-custody, and analysis process illustrated in Figure 8-1 of the QAPjP. The criteria for determining the validity of ER data at RFP are described in subsection 3.7 of the QAPjP.

The acceptance and review criteria for the following validation standards are specified in the GRRASP. The process for evaluating whether the criteria have been met are described in the validation functional guidelines documents referenced previously. The following three levels of data validity have been established for the ER activities at the RFP.

- **Valid** - Data meets the following seven objective standards, where applicable:
 - Analytical methods followed
 - Sufficient number and type of QC samples analyzed
 - Acceptance criteria for QC samples achieved
 - Detection limits achieved
 - Compounds and analytes correctly identified
 - Equipment/instrument calibration criteria achieved
 - Sample holding times met.
- **Acceptable with Qualifications** - Data meets most, but not all, objective standards. All primary validation criteria are achieved within acceptable limits (calibration, method requirements, compound and analyte identification).
- **Rejected** - Data fails to meet objective standards or fails to meet primary validation criteria.

7.3.8.4 Data Reporting

Depending on the outcome of the data validation process or the status of data validation, data are coded according to the definitions in Table 7-2. The results of the data validation will be reported in ER Department Data Assessment Summary reports. The usability of data (the criteria of which are also described in subsection 3.7 of Section 3.0 of the QAPjP) will also be addressed by the BSCP Project Manager.

The following three levels of data usability are utilized for the ER Program at the RFP:

- Data is usable for all purposes if all of the following criteria are met:
 - Data quality is classified as valid.
 - All data quality objectives are achieved.
 - All specific agreements and/or regulatory requirements are met.
- Data is considered usable for some purposes if any of the following conditions occur:
 - Data quality is classified as valid or acceptable with qualifications. (Rejected data may be usable for some very limited purposes such as screening.)
 - Not all data quality objectives are achieved.
 - All specific program requirements are not met.
- Data may be unusable if any or all of the following conditions are met:
 - Data quality is classified as rejected.
 - Data quality objectives are not achieved.
 - Specific program requirements are not met.

TABLE 7-2
DATA VALIDATION CODES

| CODE | DEFINITION | INCLUDE IN DATA ANALYSIS? |
|-------------|---|--------------------------------------|
| J | Estimated Result | Yes |
| A | Acceptable Result | Yes |
| JA | Acceptable Result for Estimated Value | Yes |
| R | Rejected Result | No |
| V | Valid Result | Yes |
| Y | Not Yet Validated, Validation in Progress | Yes |
| Z | Validation Not Required | Yes |

Note: Those data qualified with a "U" but having validation code of "JA" are still non-detects.

7.4 PROCUREMENT DOCUMENT CONTROL

Procurement documents for items and services, including contractor services for conducting field investigations, analytical laboratories, and data validation will be prepared, handled, and controlled in accordance with the requirements and methods specified in Section 4.0 of the QAPjP. Items and services used in support of BSCP activities will be procured according to instructions in EMD Administrative Procedure 3-21000-ADM-04.01, Procurement Document Control.

7.5 INSTRUCTIONS, PROCEDURES, AND DRAWINGS

This work plan describes the activities to be performed in the BSCP. This plan will be reviewed and approved in accordance with the requirements for instructions, procedures, and drawings outlined in Section 5.0 of the QAPjP.

EMD OPS approved for use and their applicability are identified in Table 5-1. Any additional quality-affecting procedures proposed but not identified here will be developed and approved as required in Section 5.0 of the QAPjP prior to performing the affected activity.

Changes and variances to approved OPs and the BSCP work plan will be documented through preparation of Document Modification Requests (DMRs), which will be prepared, reviewed, and approved in accordance with requirements specified in Section 5.0 of the QAPjP.

7.6 DOCUMENT CONTROL

The following documents will be controlled in accordance with Section 6.0 of the QAPjP:

- *Rocky Flats Plant Background Soils Characterization Program Work Plan*
- *Rocky Flats Plant Site-Wide Quality Assurance Project Plan for CERCLA Remedial Investigation/Feasibility Studies and RCRA Facility Investigations/Corrective Measures Studies Activities (EG&G, 1990)*
- EMD OPs referenced in Table 5-1 and any additional procedures not yet identified that may be required to implement BSCP activities.

7.7 CONTROL OF PURCHASED ITEMS AND SERVICES

Contractors that provide services to support the activities described in the BSCP work plan will be selected and evaluated as described in Section 7.0 of the QAPjP. This includes pre-award evaluation/audit of proposed contractors as well as periodic audit of the acceptability of contractor performance during the life of the contract. Any items or materials that are purchased for use during the BSCP investigations that have the ability to affect the quality of the data will be inspected upon receipt.

7.8 IDENTIFICATION AND CONTROL OF ITEMS, SAMPLES, AND DATA

Identification and control of items, samples, and data includes a discussion of:

- sample containers
- sample identification
- chain-of-custody.

7.8.1 Sample Containers

Appropriate volumes, containerization, and holding times for the BSCP soil samples are presented in Table 5-5.

7.8.2 Sample Identification

BSCP samples will be labeled and identified in accordance with Section 8.0 of the QAPjP and EMD OP FO.13, Containerizing, Preserving, Handling, and Shipping of Soil and Water Samples. Samples will have a unique identification code that traces the sample to the source(s) and indicates the media type, the sequential number for the sample, date of sample collection, the sampler(s), sampling method, and conditions prevailing at the time of sampling. An example sample number is SS00001DM where "SS" indicates the media type is surface soil, "00001" is the sequential sample number, and "DM" is the subcontractor identification for Dames & Moore.

7.8.3 Chain-of-Custody

Sample chain-of-custody will be maintained through the application of EMD OP FO.13, Containerizing, Preserving, Handling, and Shipping of Soil and Water Samples, and as illustrated in Figure 8-1 of the QAPjP for all environmental samples collected during field investigations.

7.9 CONTROL OF PROCESSES

The overall process of collecting samples, performing analysis, and entering the data into a database is a process that requires control. The process is controlled through a series of written procedures that govern and document the work activities. A process diagram is shown in Section 8.0 of the QAPjP.

7.10 INSPECTION

Inspection of BSCP activities and items (including procured materials and construction items) may be inspected in accordance with the requirements for inspections specified in Section 10.0 of the QAPjP.

7.11 TEST CONTROL

The BSCP does not include activities which require test control. Therefore, test control requirements specified in Section 11.0 of the QAPjP are not applicable.

7.12 CONTROL OF MEASURING AND TEST EQUIPMENT

Control of Measuring of Test Equipment (M&TE) includes discussion of field and laboratory equipment for the BSCP.

7.12.1 Field Equipment

At present, field measurements during BSCP sample acquisition are not planned. However, if field measurements (i.e., high-purity germanium detector survey, fiddler survey) are performed, each piece of field equipment required will have a logbook for recording daily source checks and a file that contains:

- Specific model and instrument serial number
- Operating instructions
- Routine preventative maintenance procedures, including a list of critical spare parts to be provided or available in the field
- Calibration methods, frequency, and description of the calibration solutions
- Standardization procedures (traceability to nationally recognized standards).

This information will, in general, conform to the manufacturer's recommended operating instructions or will explain deviation from the instructions.

7.12.2 Laboratory Equipment

Laboratory analyses will be performed by contracted laboratories. The equipment used to analyze environmental samples will be calibrated, maintained, and controlled in accordance with the requirements contained in the specific analytical protocols used as specified in the GRRASP. Laboratories are required to submit calibration procedures to EG&G for review and approval. Initial and continuing calibrations data for analytical equipment used will be included in the data packages submitted to EG&G by the laboratories.

7.13 HANDLING, STORAGE, AND SHIPPING

Handling, storage, and shipping include activities relevant to sample packaging, transporting, and storage. These activities will be conducted in accordance with EMD OP FO.13, Containerizing, Preserving, Handling, and Shipping of Soil and Water Samples. Maximum sample holding times, sample volumes, and sample containers are specified in Table 5-5.

7.14 STATUS OF INSPECTION, TEST, AND OPERATIONS

The requirements for the identification of inspection, test, and operating status will be implemented as specified in Section 14.0 of the QAPjP. A log specifying the status of all soil profile trenches will be maintained by the Field Activities Task Leader.

7.15 CONTROL OF NONCONFORMANCES

The requirements for the identification, control, evaluation, and disposition of nonconforming items, samples, and data will be implemented as specified in Section 15.0 of the QAPjP. Nonconformances identified by the implementing contractor will be submitted to EMD QAPM for processing as outlined in the QAPjP.

7.16 CORRECTIVE ACTION

The requirements for the identification, documentation, and verification of corrective actions for conditions adverse to quality will be implemented as outlined in Section 16.0 of the QAPjP. Conditions adverse to quality which are identified by the implementing contractor, will be documented and submitted to EMD QAPM for processing also as outlined in Section 16.0 of the QAPjP.

7.17 QUALITY ASSURANCE RECORDS

QA records will be controlled in accordance with OPS-FO.02, Field Document Control. QA records to be generated during BSCP activities include, but are not limited to:

- Field Logs and Data Record Forms (e.g., soil sample collection notebooks/logs)
- Calibration Records
- Soil Profile (trench) Logs
- Sample Collection and Chain-of-Custody Records
- Laboratory Sample Data Packages
- Work Plan/Field Sampling Plan
- QAPjP/QAA
- Audit/Surveillance/Inspection Reports
- Nonconformance Reports
- Corrective Action Documentation
- Data Validation Results
- Data Reports
- Procurement/Contracting Documentation
- Training/Qualification Records
- Inspection Records.

All QA records generated during the planning, implementation, and closure of the activities for the BSCP will be submitted to the EMD Custodian for processing according to the EMD QA records system described in Section 17.0 of the QAPjP.

7.18 QUALITY VERIFICATION

The requirements for the verification of quality will be implemented as specified in Section No. 18 of the QAPjP. EG&G will conduct audits of the laboratory contractor as specified in the GRRASP, Parts A and B. The EMD QAPM will develop a surveillance schedule with the surveillance intervals based on the importance and complexity of each sampling/analytical activity. Intervals will also be based on the schedule contained in Section 8.0 of this work plan.

Examples of some specific tasks that may be monitored by the surveillance program are as follows:

- Pit/trench installations for soil profile sampling
- Surface soil sampling
- Records management
- Data verification, validation, and reporting.

Audits of contractors providing field investigation, construction, and analytical support services will be performed at least annually or once during the life of the project, whichever is more frequent. Audits are arranged by the EMD QAPM.

A Readiness Review will be conducted by the EMD QAPM prior to the implementation of BSCP field investigation activities. The readiness review will determine if all activity prerequisites have been met that are required to begin work. The applicable requirements of the QAPjP and this work plan will be addressed.

7.19 SOFTWARE CONTROL

The requirements for the control of software will be implemented as specified in Section 19.0 of the QAPjP. Only database software is anticipated to be used for the BSCP field sampling activities. Operating procedures applicable to the use of the database storing environmental data can be found in EMD OP FO.14, Field Data Management. It is anticipated that the following commercial or public domain software packages may be used for data analysis:

- dBase
- Quattro Pro
- SPSS
- Paradox
- Systat
- Geo-EAS
- Microsoft Excel.

8.0 SCHEDULE

This section presents the schedule for completion of the BSCP. Figure 8-1 depicts the bar-chart schedule. The schedule assumes that the work plan is approved by all parties by May 15, 1994. Surface soil sampling is scheduled to begin in mid-May and continuing through July, 1994. Soil profile (test pit) sampling will commence following surface soil sampling, and will end during early October. It is anticipated that a Phase I report, containing all results of the surface soil sampling, will be completed during July, 1995. A Phase II report, incorporating the soil profile results, is expected to be completed during early October, 1995.

**Workplan Review
& Revision**



**Surficial
Soil Sampling**



**Surface Soil Lab Analysis
& Data Validation**



**Surface Soil Draft Report
Preparation (Phase I Report)**



**Phase I Report
Review & Revision**



**Soil Profile
Sampling**



**Soil Profile Lab Analysis
& Data Validation**



Soil Profile Draft Report



**Phase II Review
& Revision**



**Phase II
Report
Oct. 6,
1995**

**Phase I
Report
July 15,
1995**

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FIGURE 8-1

SCHEDULE

9.0 BIBLIOGRAPHY

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APPENDIX A
INFORMATION FROM PREVIOUS INVESTIGATIONS

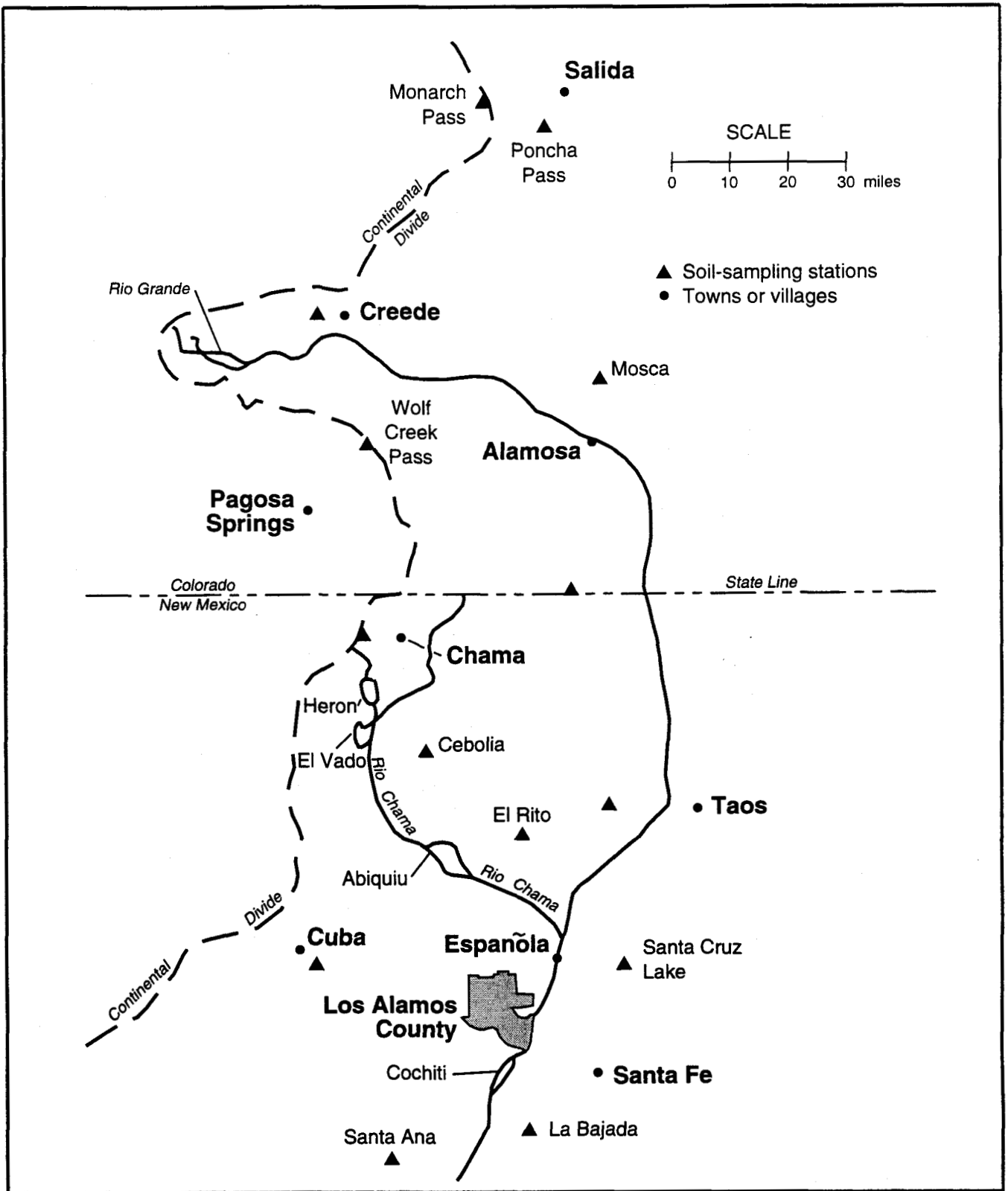


APPENDIX A

INFORMATION FROM PREVIOUS INVESTIGATIONS

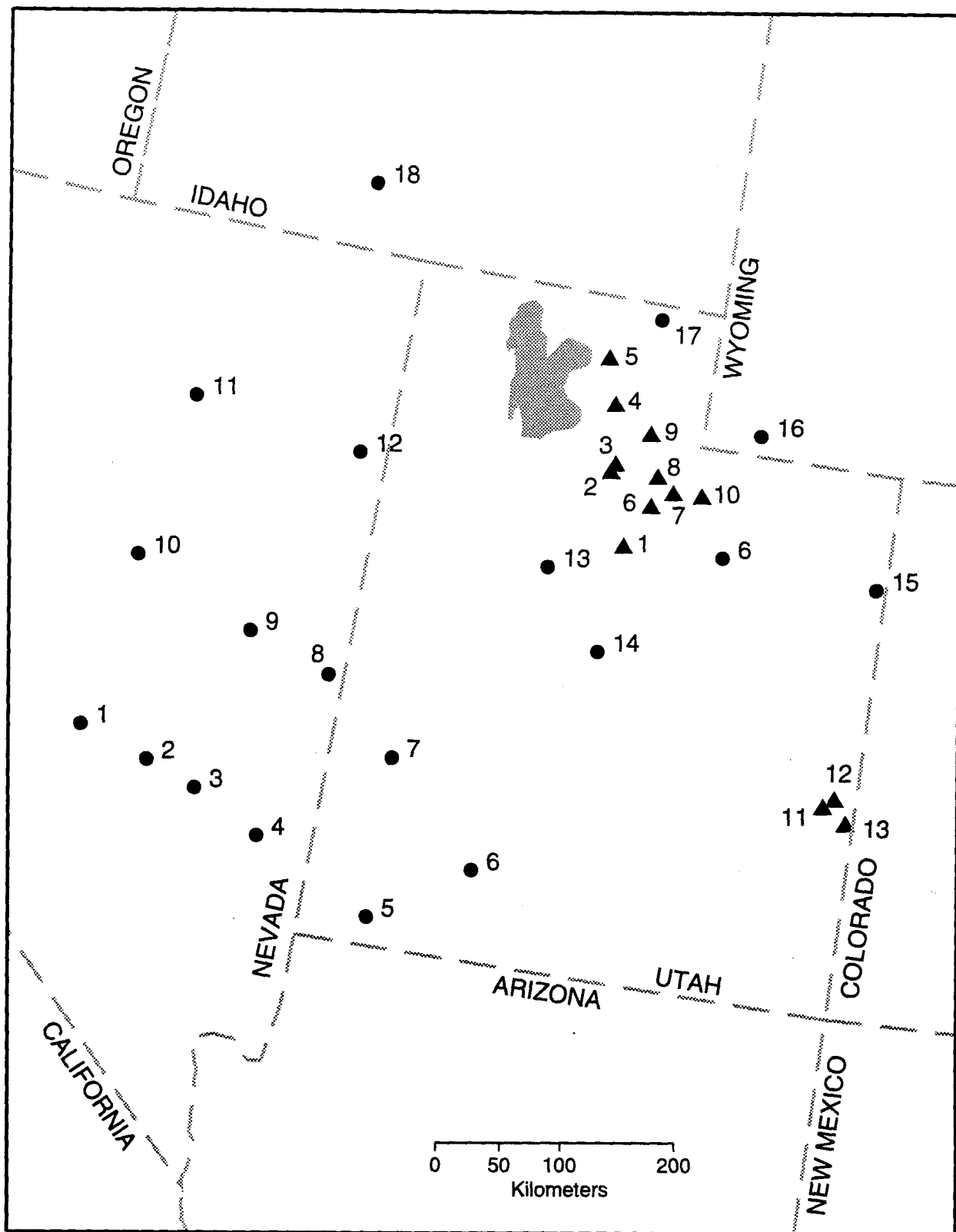
The figures contained in Appendix A depict surface soil sampling locations of relevant Pu studies, the variability of U in surface soils, and the on-site surface soil sampling locations for analytes.

Figure A-1 presents the locations in northern New Mexico and southern Colorado sampled by Purtymun et al. (1990). The 1971 and 1974 locations sampled by Hardy (1976) are shown in Figure A-2. Figure A-3 demonstrates Michels' sampling locations along three transects in the United States Great Plains. McArthur and Miller (1989) collected soil samples throughout the western United States as illustrated in Figure A-4. Krey and Hardy (1970) collected soil samples from 33 sites near RFP as shown in Figure A-5. The eight communities sampled by Lawton (1989) are presented in Figure A-6. Figure A-7 demonstrates the 28 sites where Poet and Martell (1972) gathered samples. Figure A-8 shows the sample locations in lands adjacent to RFP that were sampled by Illsley and Hume (1979). The CDH (Terry, 1991) collected samples from 18 sectors within a 6.2 km (10 mi) radius of the plant as illustrated in Figure A-9. In 1990, Western Technologies, Inc. (1991) collected samples from approximately 478 acres of land within three gravel lease properties located on the RFP West Buffer Zone (Figure A-10). The Radioecology Group from Colorado State University collected and analyzed data from five areas west of the plant designated as Plots GP, NW, FV, WC, and SW shown in Figure A-11. A number of sampling studies have been conducted in the OUs presented in Figure A-12. The variability of U in surface soils is illustrated in Figure A-13. The on-site surface soil locations for analyte sampling are demonstrated in Figure A-14.



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FIGURE A-1
PURTYMUN ET AL. (1990)
SOIL SAMPLING LOCATIONS

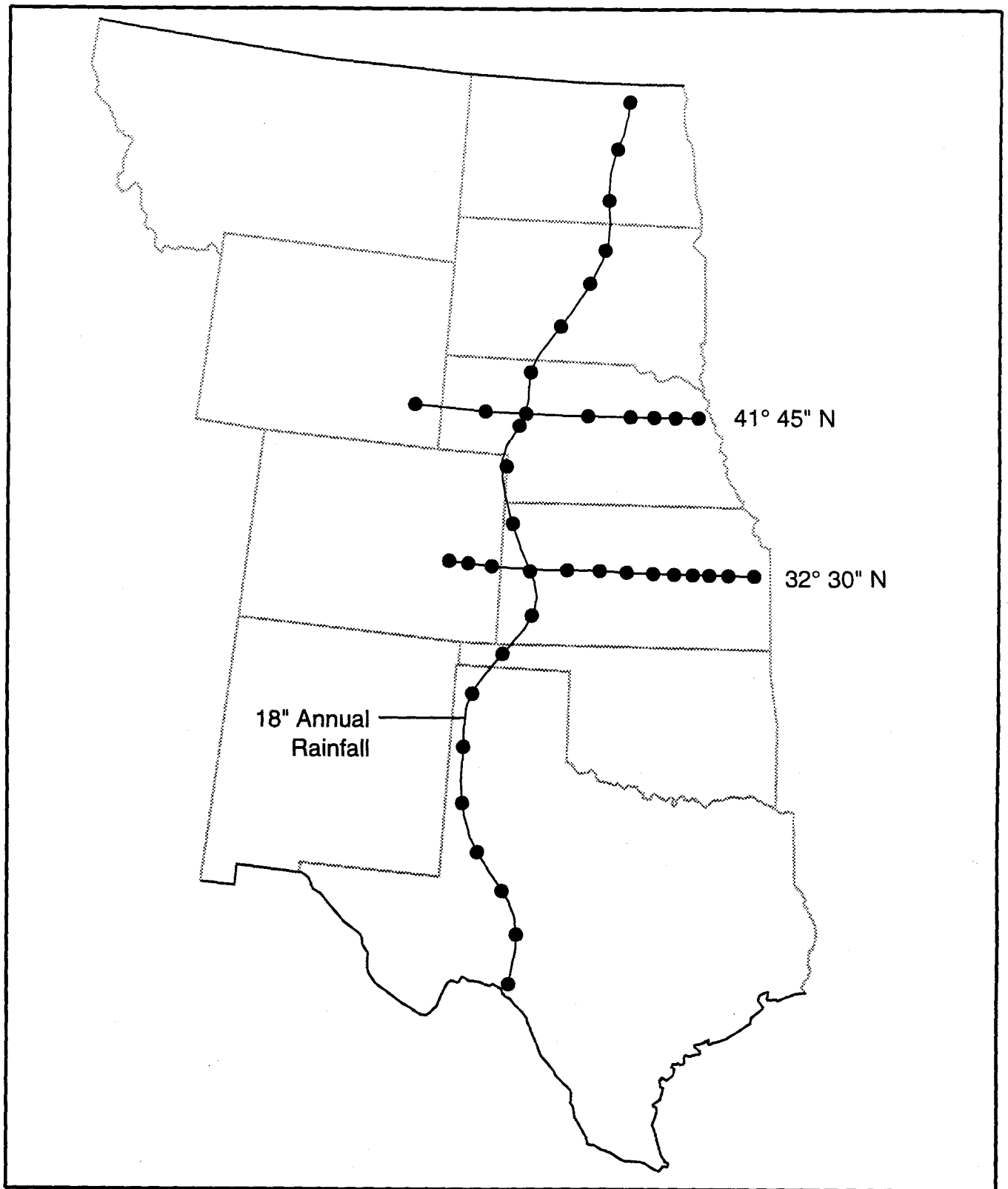


- 1971 Soil Sampling
- ▲ 1974 Soil Sampling

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FIGURE A-2

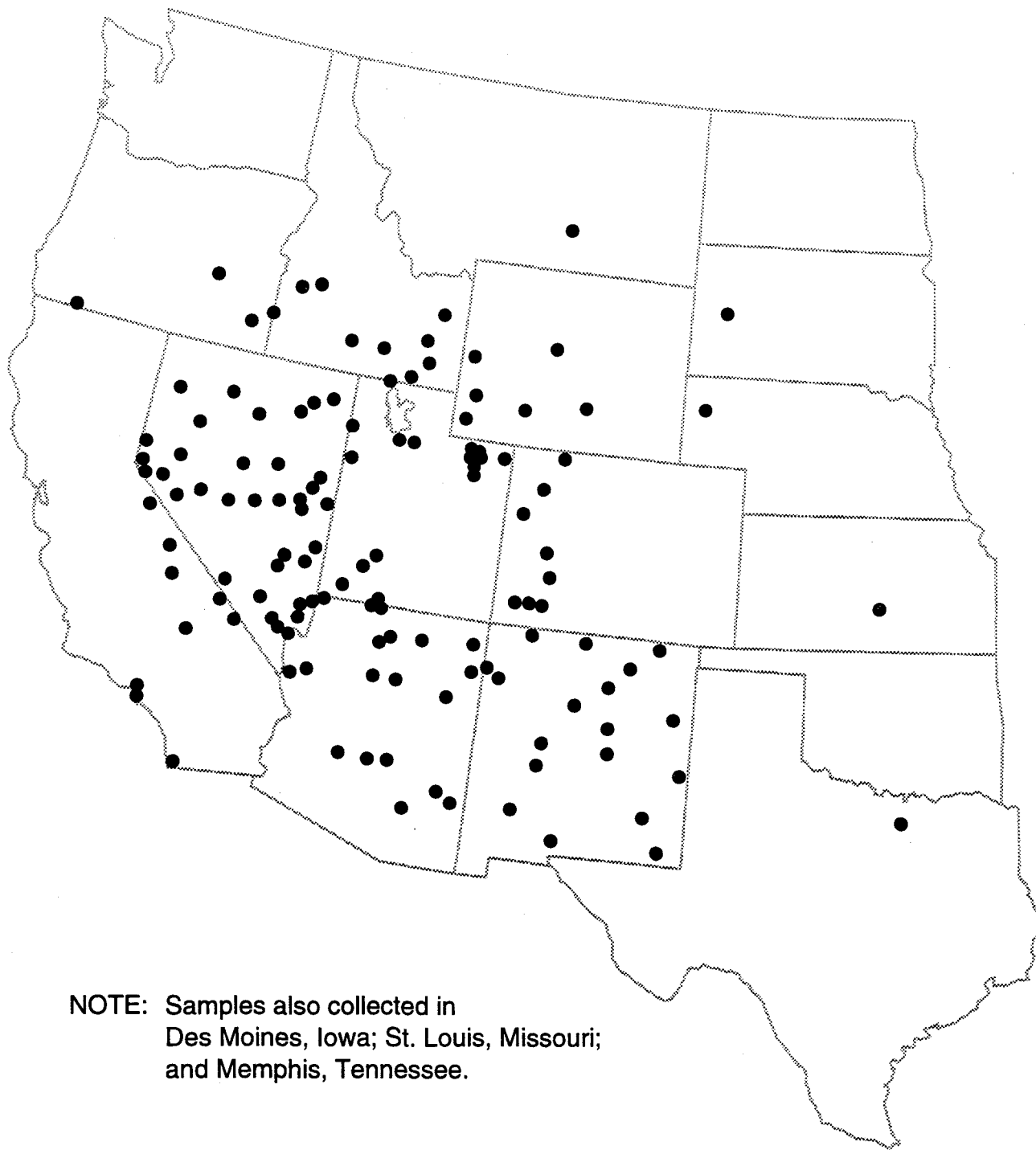
1971 AND 1974 SOIL SAMPLING
 LOCATIONS (HARDY, 1976)



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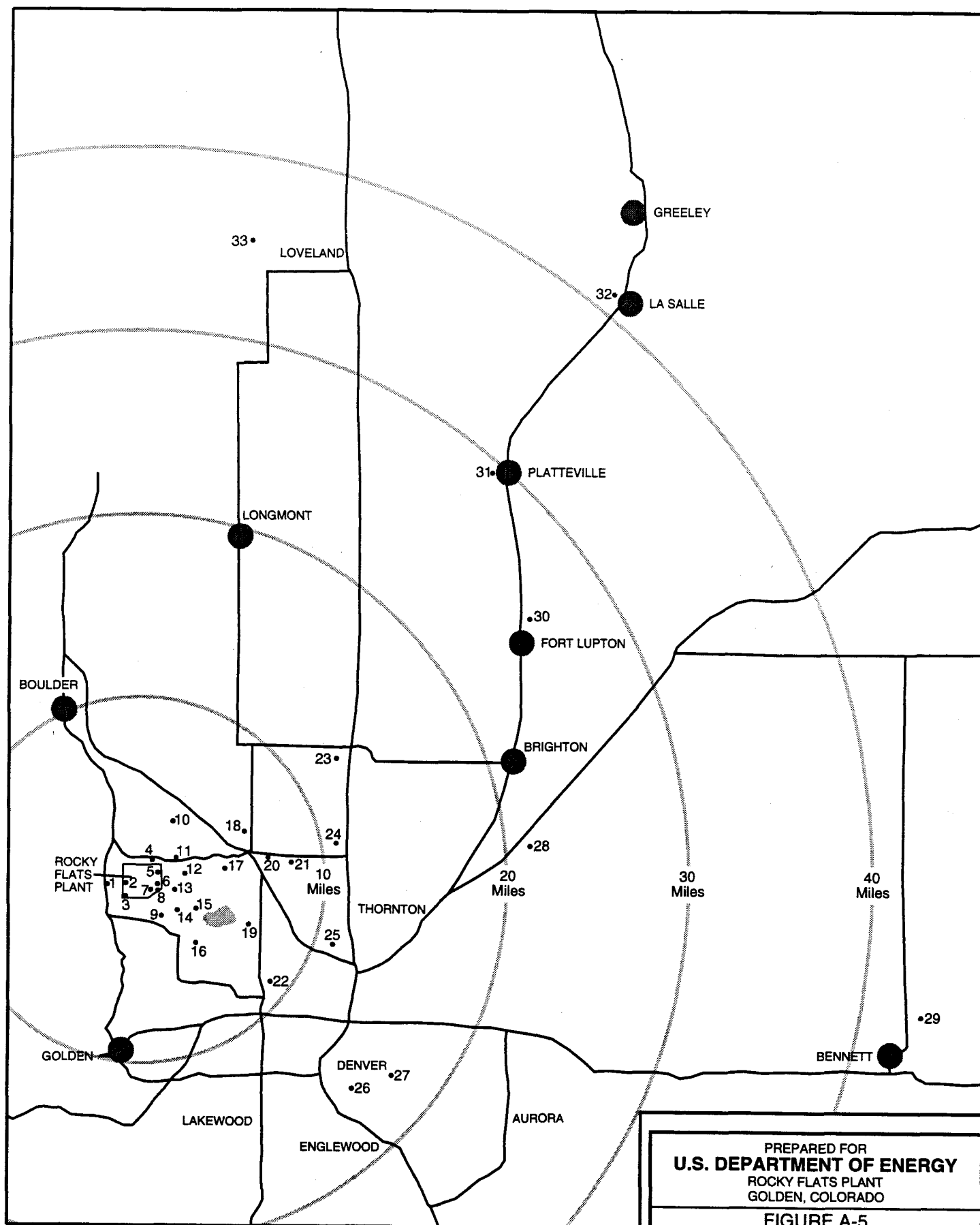
FIGURE A-3

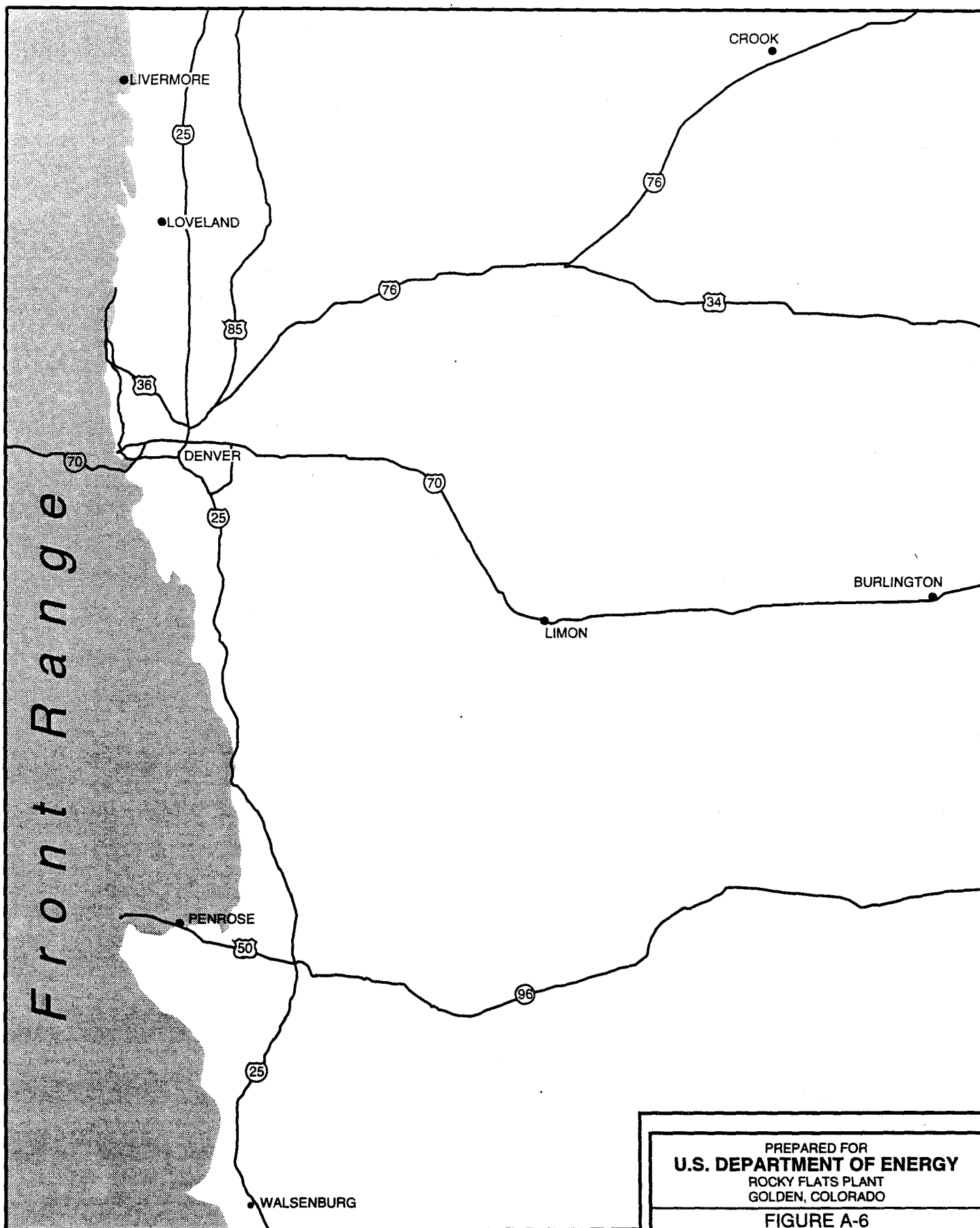
SOIL SAMPLING LOCATIONS
IN U.S. GREAT PLAINS (MICHELS)



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FIGURE A-4
SOIL SAMPLE LOCATIONS
WESTERN UNITED STATES
(McARTHUR AND MILLER, 1989)

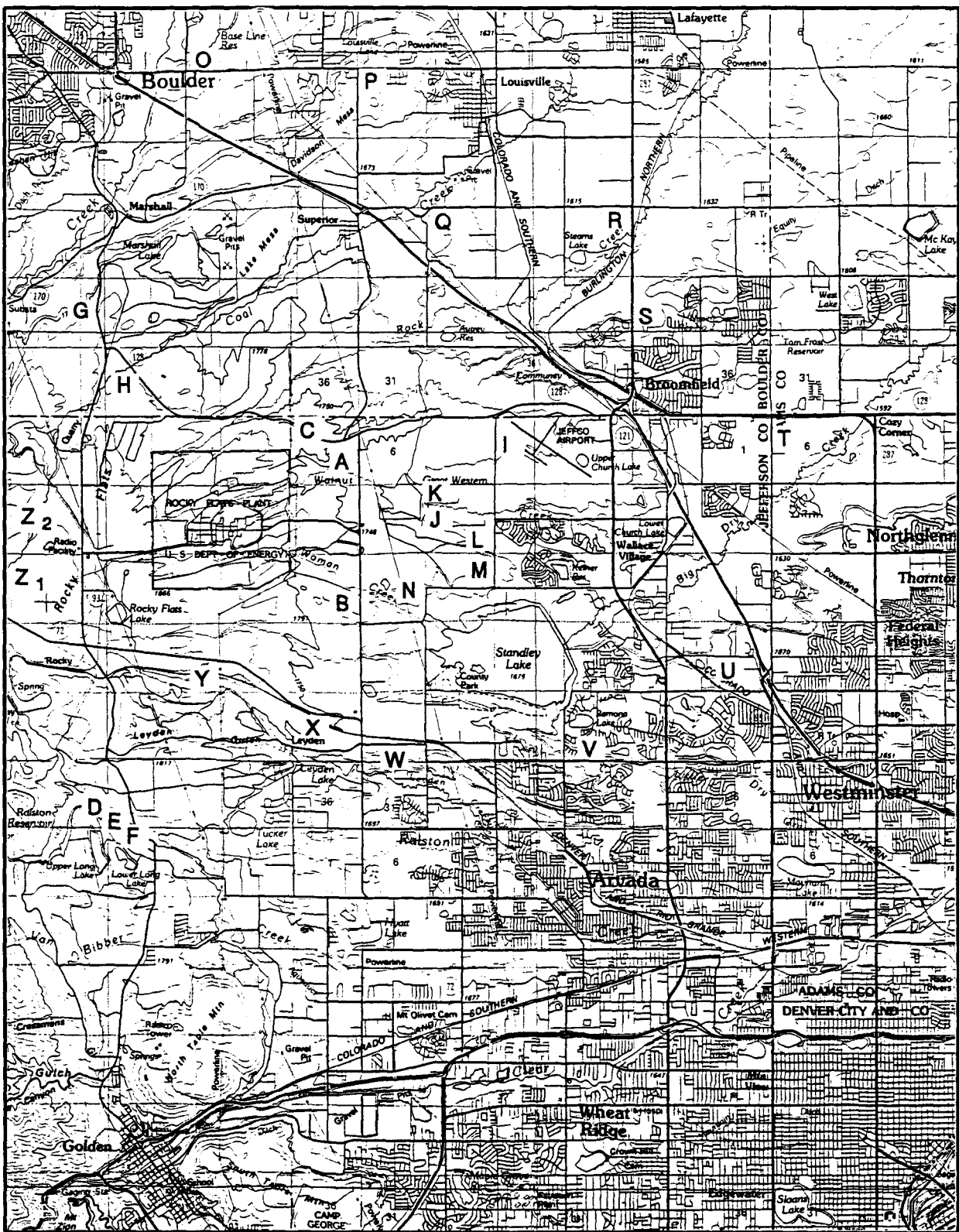




NOTE: Soil samples were also taken in
Springfield, Colorado.

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FIGURE A-6
SOIL SAMPLING LOCATIONS
NEAR EIGHT COMMUNITIES
(LAWTON, 1989)

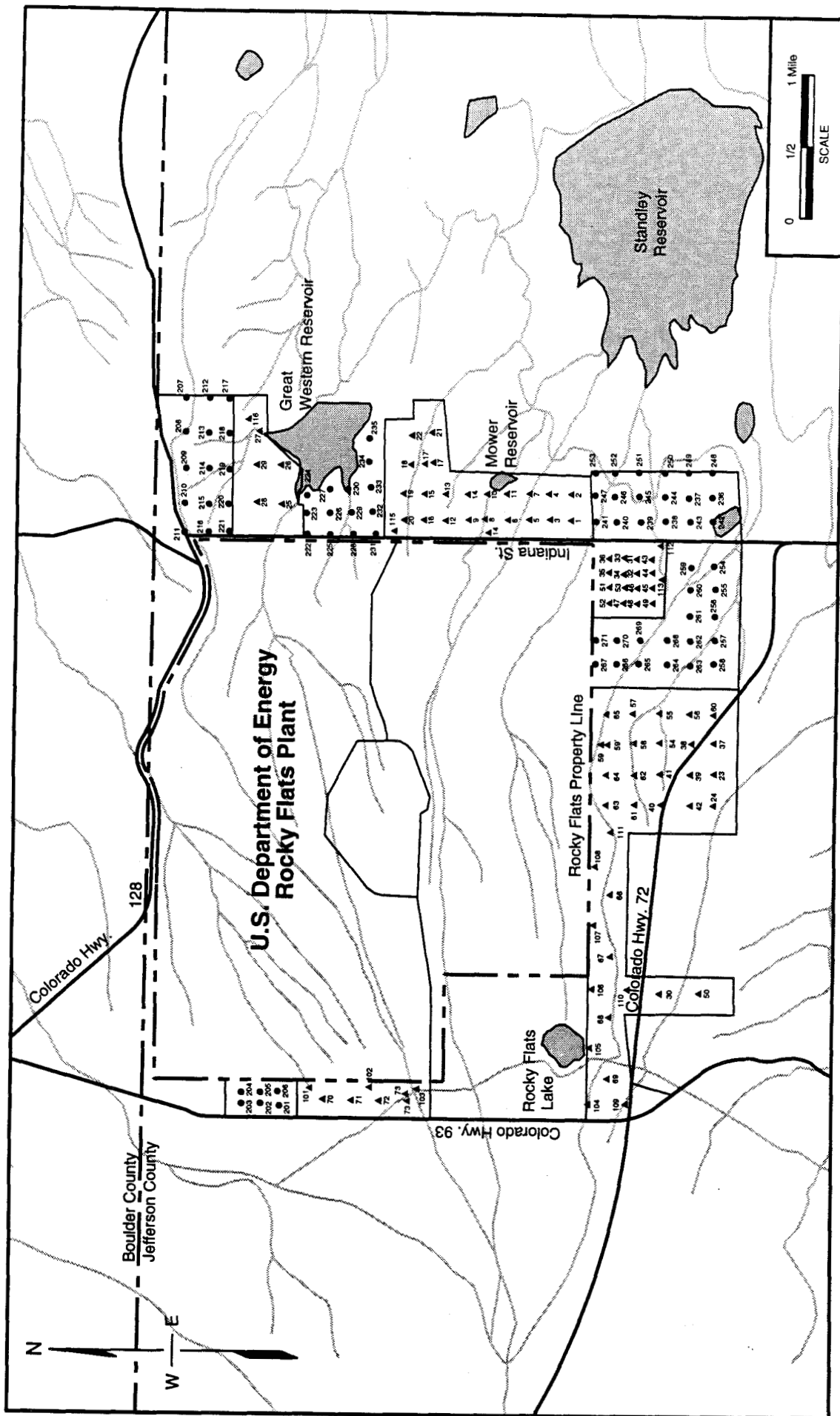


0 1 MILE 2 MILES 4 MILES

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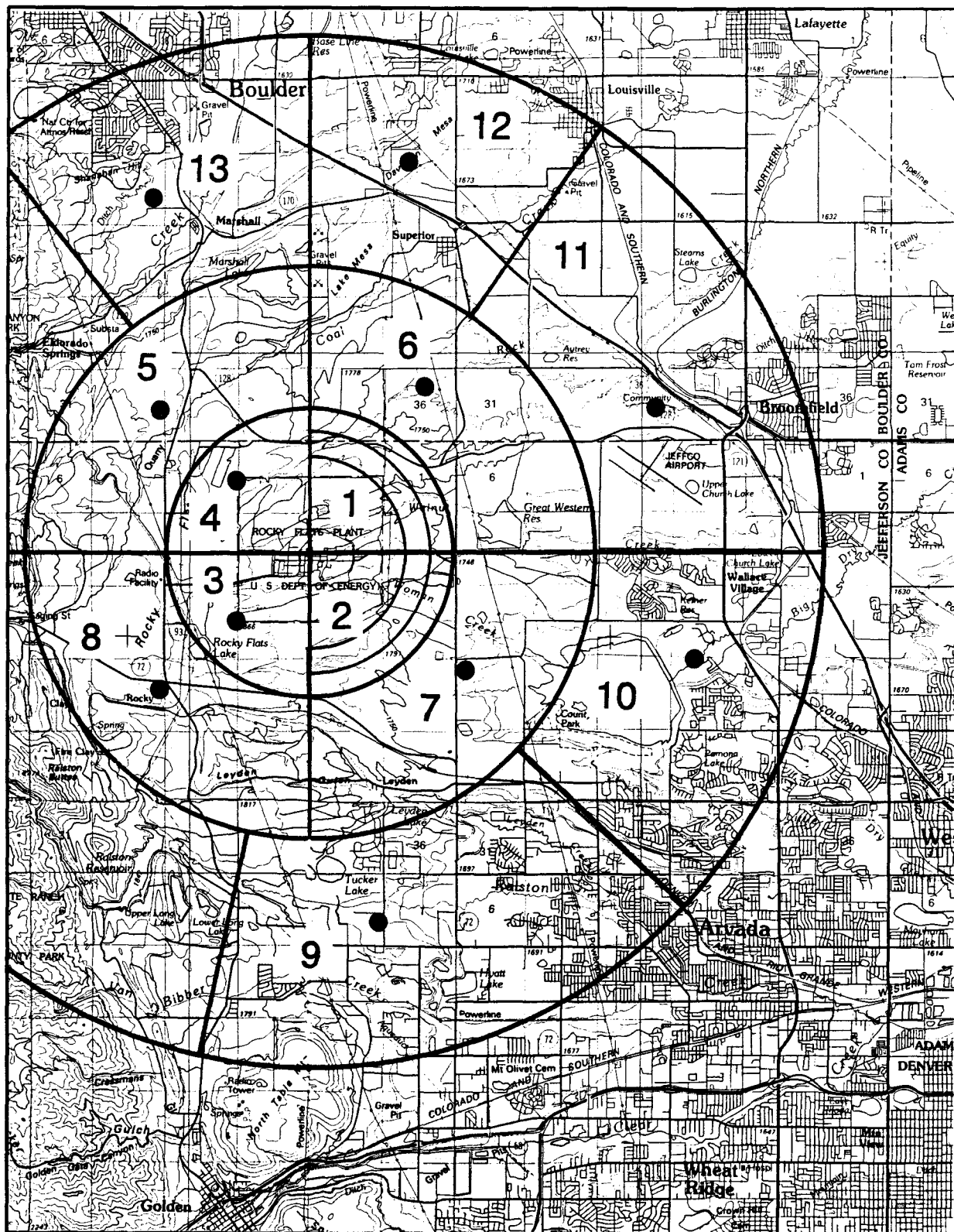
FIGURE A-7

SOIL SAMPLE LOCATIONS
POET AND MARTELL (1972)



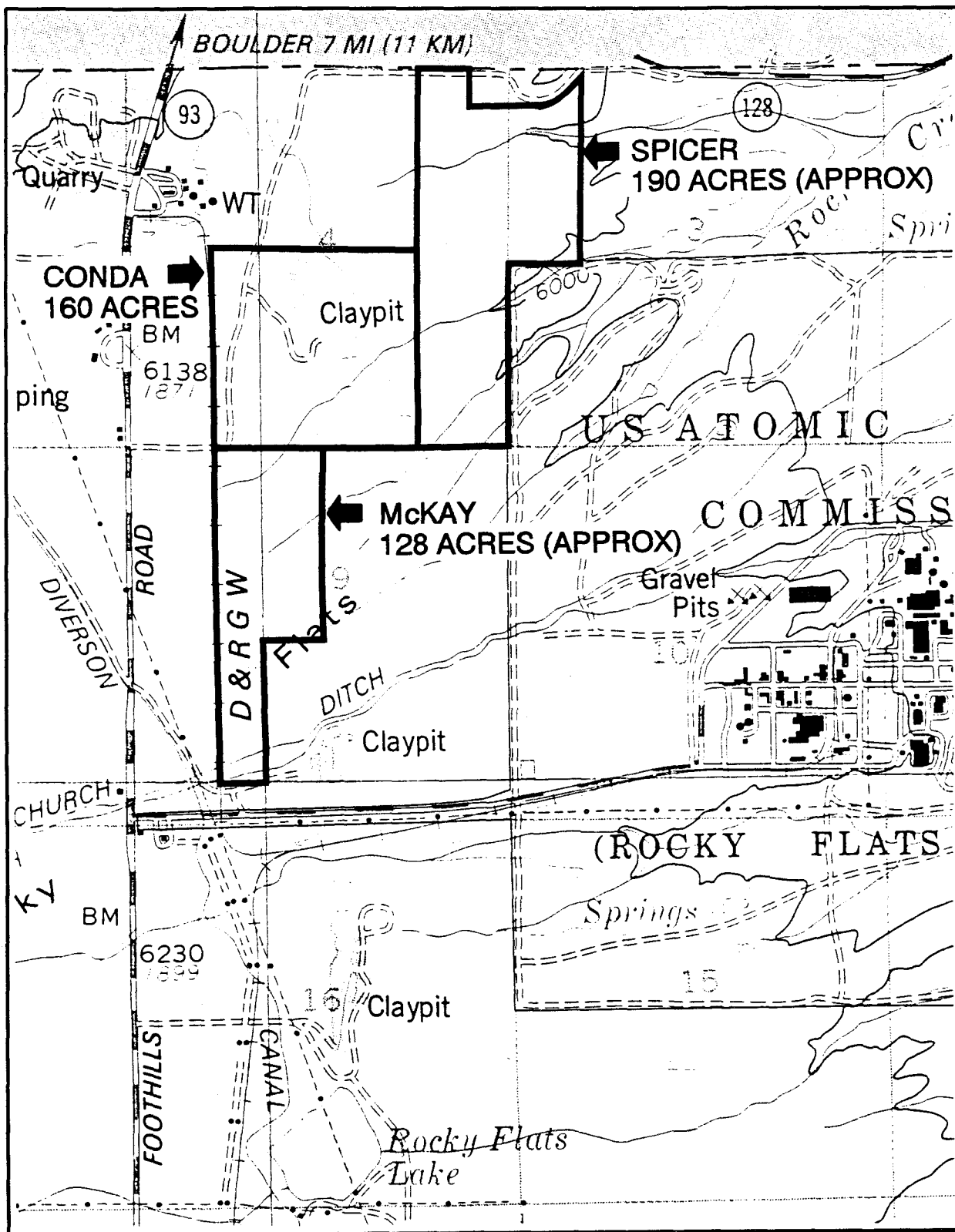
PREPARED FOR
U.S. DEPARTMENT OF ENERGY
 ROCKY FLATS PLANT
 GOLDEN, COLORADO

FIGURE A-8
 SOIL SAMPLE LOCATIONS
 ILLSLEY AND HUME (1979)



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 ROCKY FLATS PLANT
 GOLDEN, COLORADO

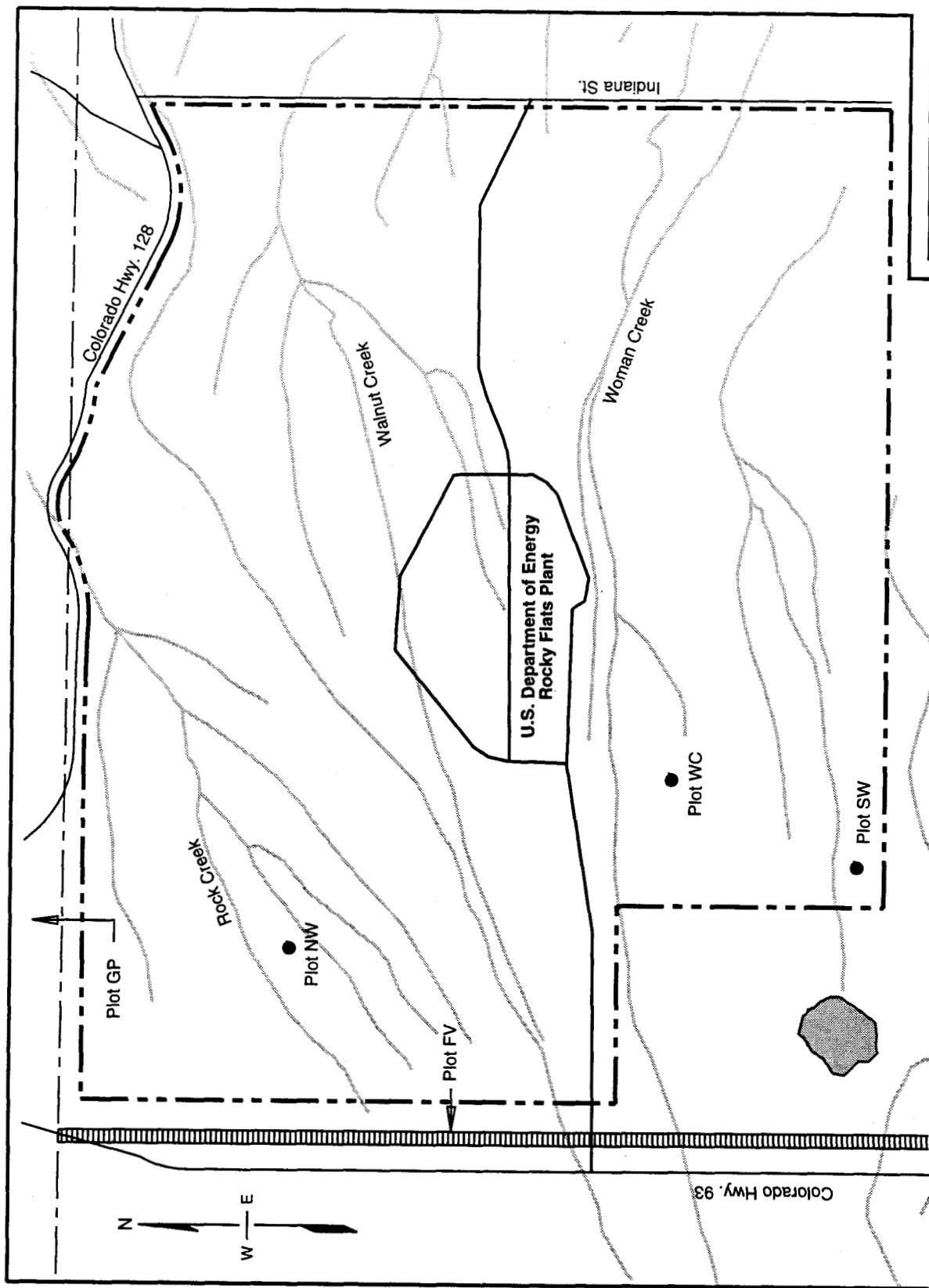
FIGURE A-9
 COLORADO DEPARTMENT OF
 HEALTH SOIL SAMPLING SECTORS,
 TERRY (1991)



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 ROCKY FLATS PLANT
 GOLDEN, COLORADO

FIGURE A-10

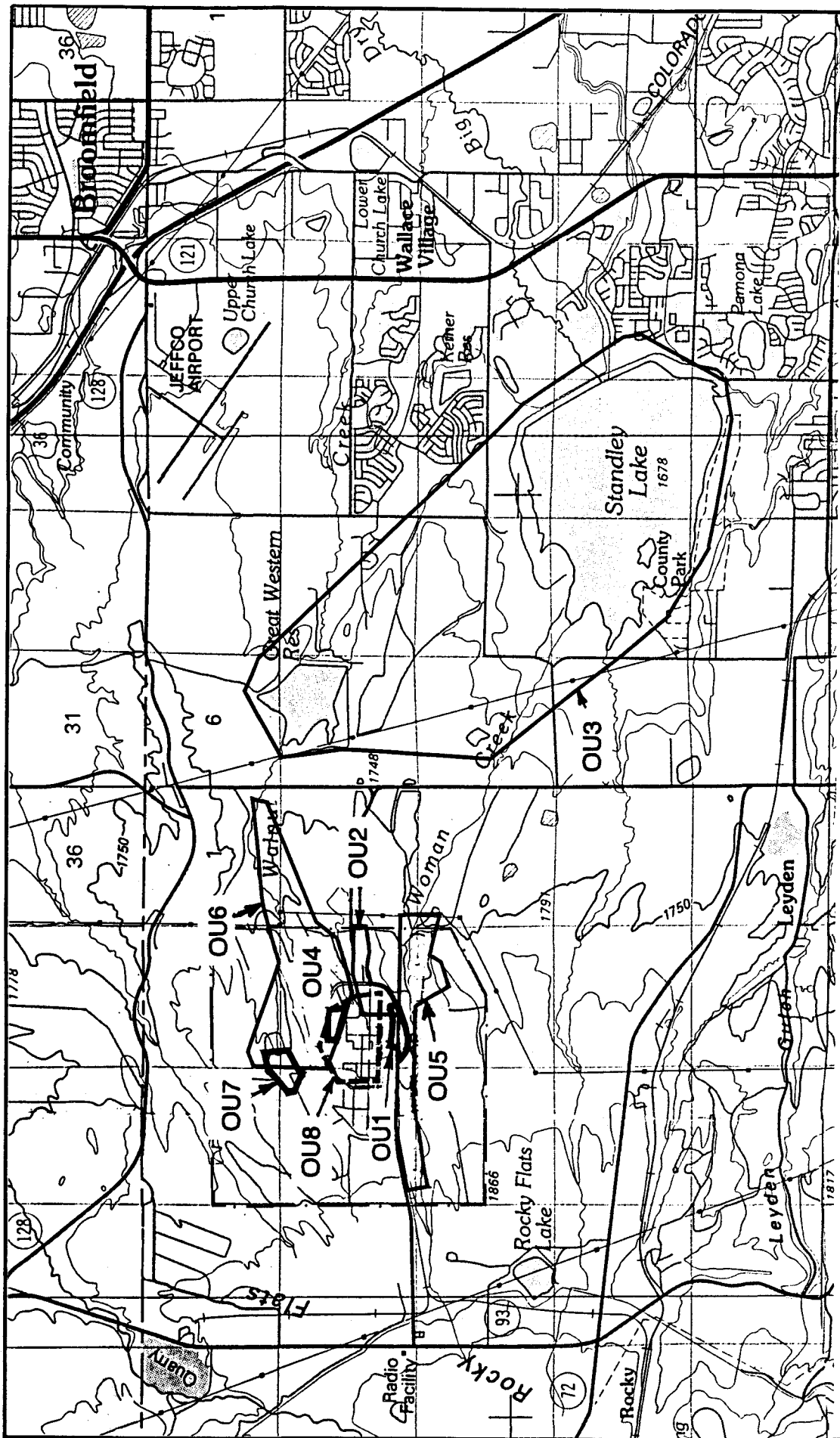
GRAVEL LEASE PROPERTIES
 WESTERN TECHNOLOGY INC., 1991



PREPARED FOR
U.S. DEPARTMENT OF ENERGY
ROCKY FLATS PLANT
GOLDEN, COLORADO

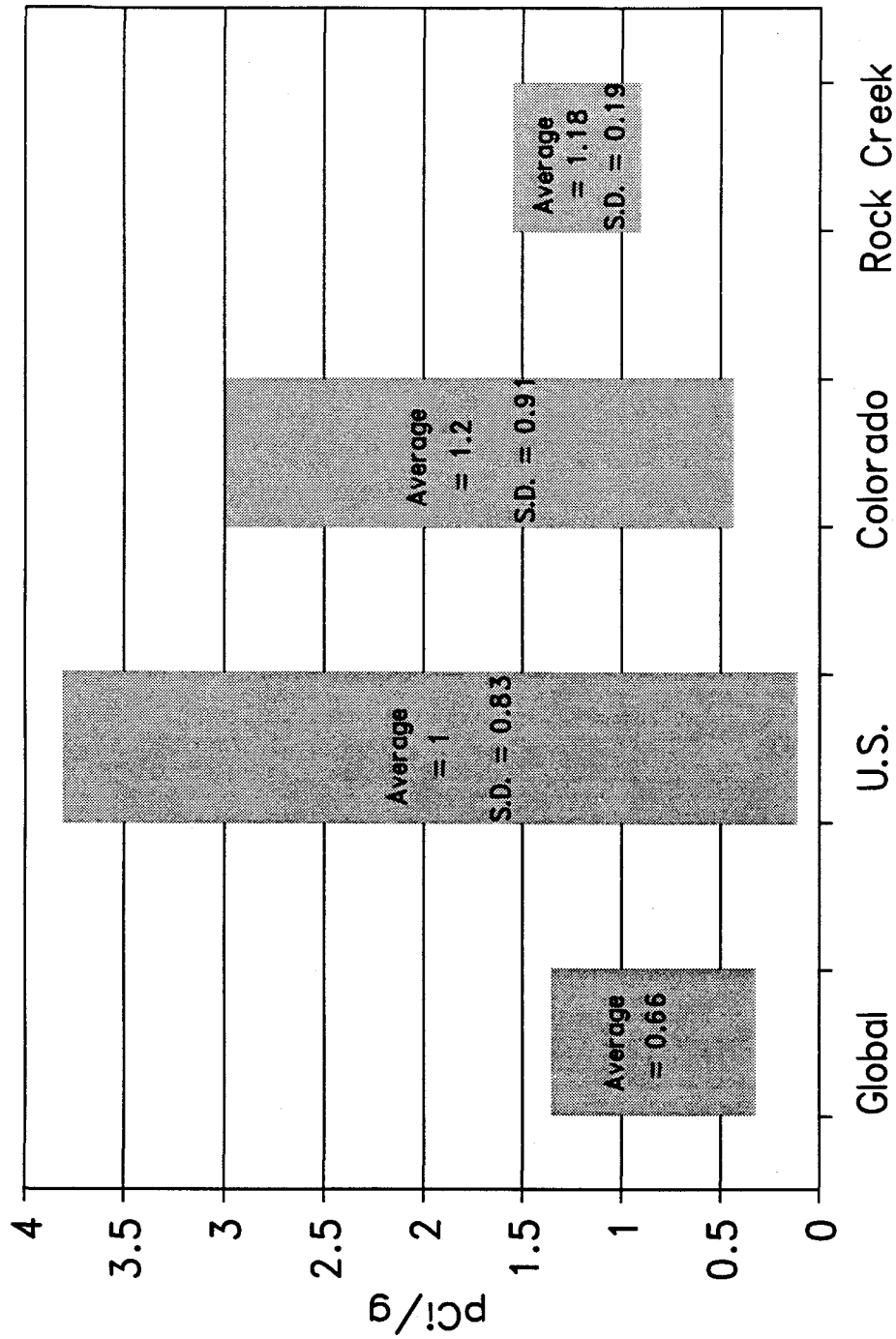
FIGURE A-11

C.S.U. PLOT SITES
ROCKY FLATS PLANT



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 ROCKY FLATS PLANT
 GOLDEN, COLORADO

FIGURE A-12
 MAP OF OPERABLE UNITS 1-8
 ROCKY FLATS PLANT



Myrick et al. (1982)

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 ROCKY FLATS PLANT
 GOLDEN, COLORADO

FIGURE A-13
 URANIUM VARIABILITY
 FROM LITERATURE
 ^{238}U (pCi/g) - TOP 6 cm

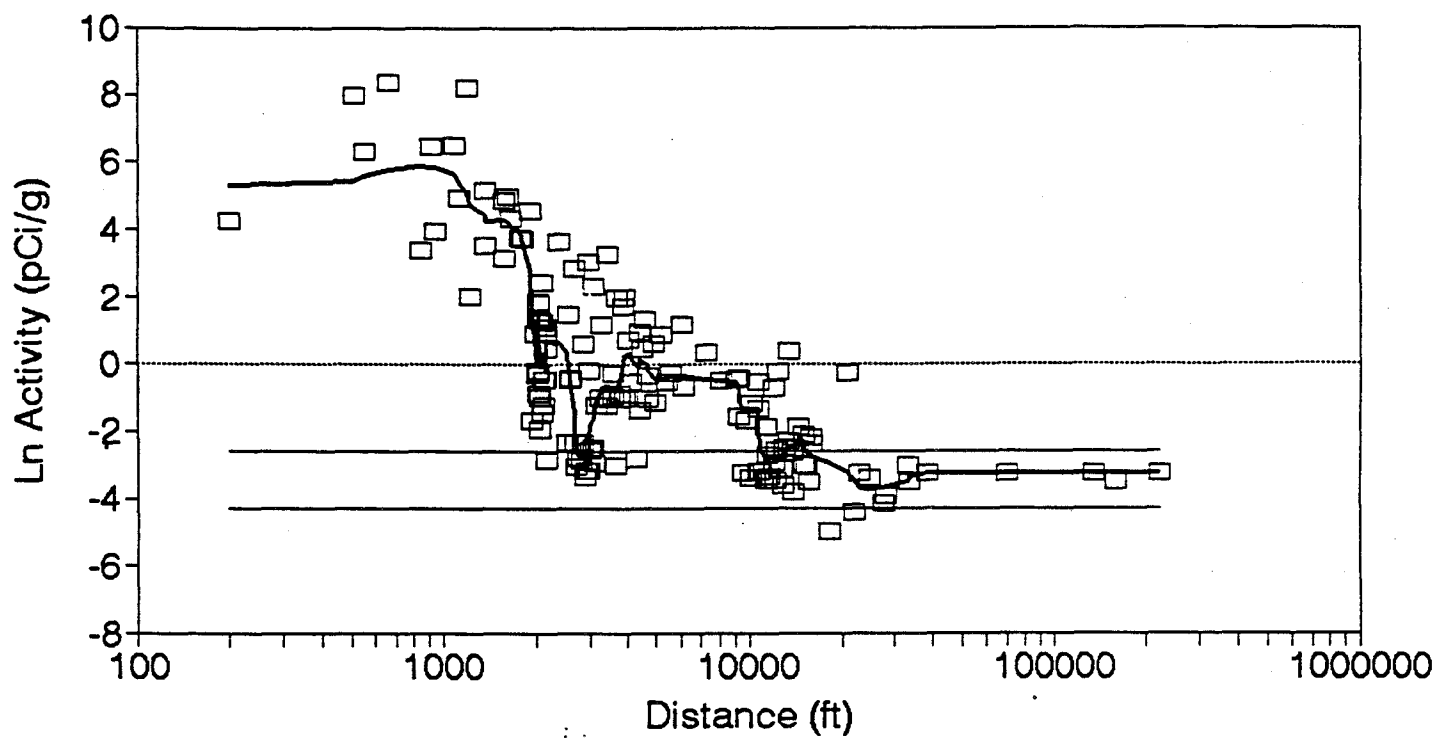
APPENDIX B

**EXPLORATORY DATA ANALYSIS RESULTS
FALLOUT RADIONUCLIDES**



PLUTONIUM-239/240

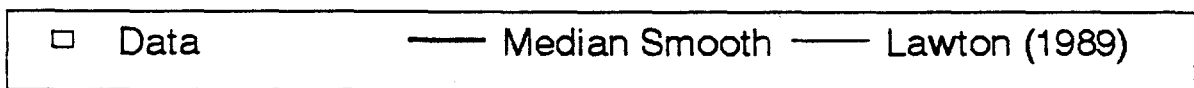
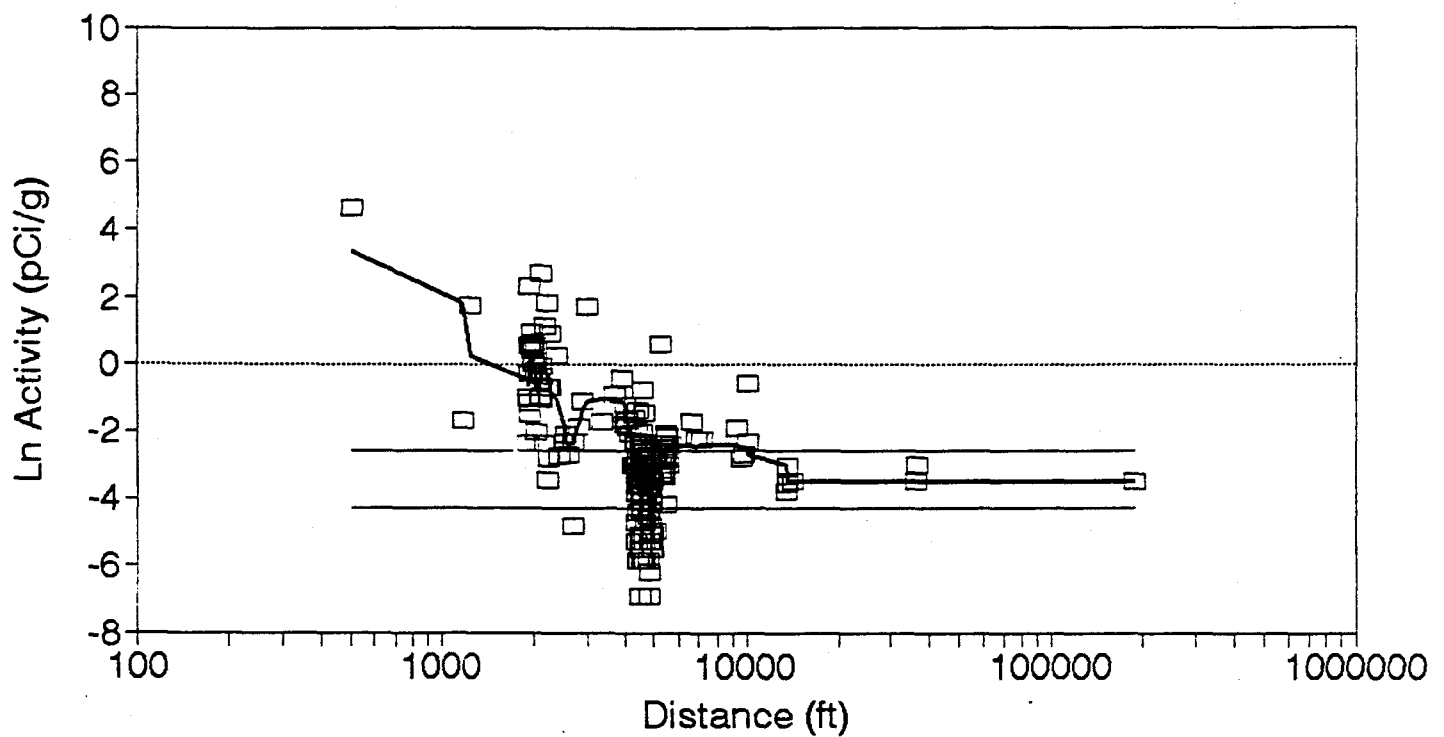
Sector 1



□ Data — Median Smooth — Lawton (1989)

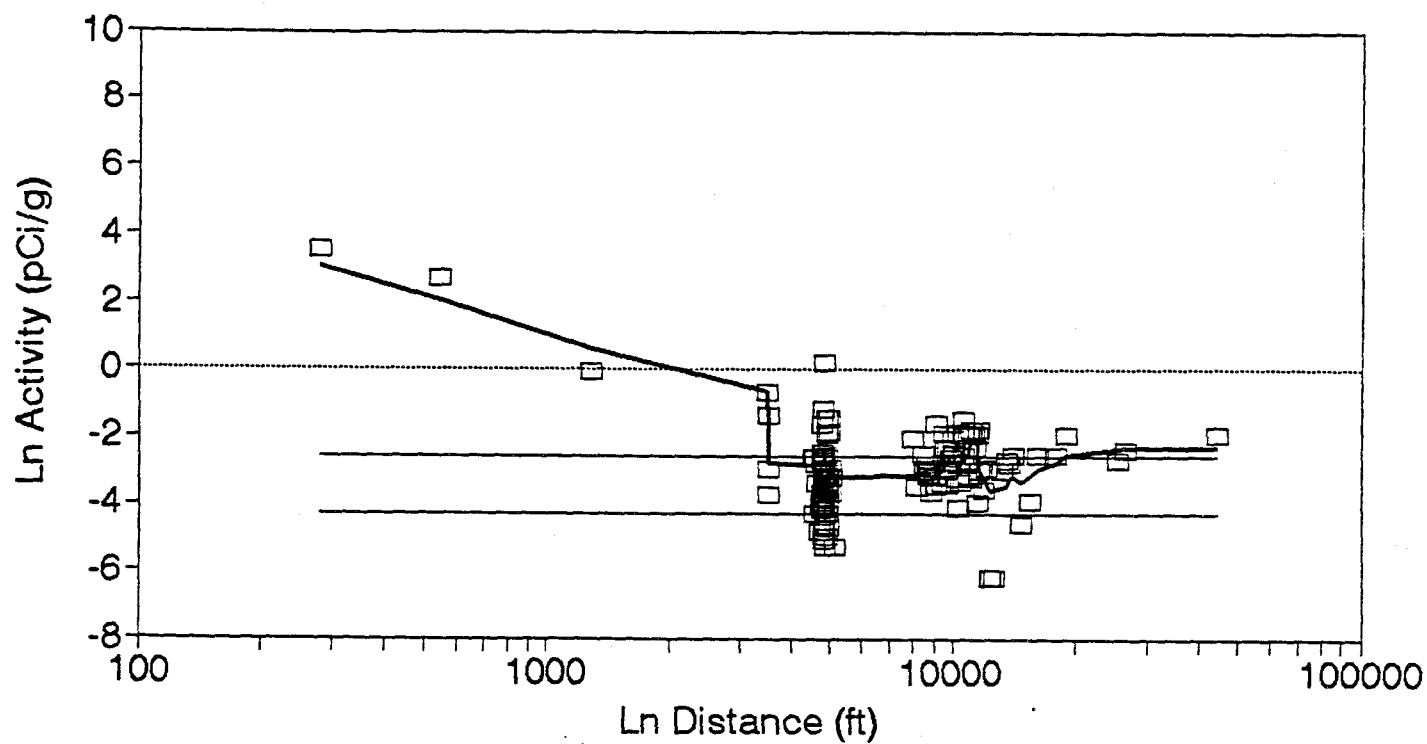
PLUTONIUM-239/240

Sector 2



PLUTONIUM-239/240

Sector 3



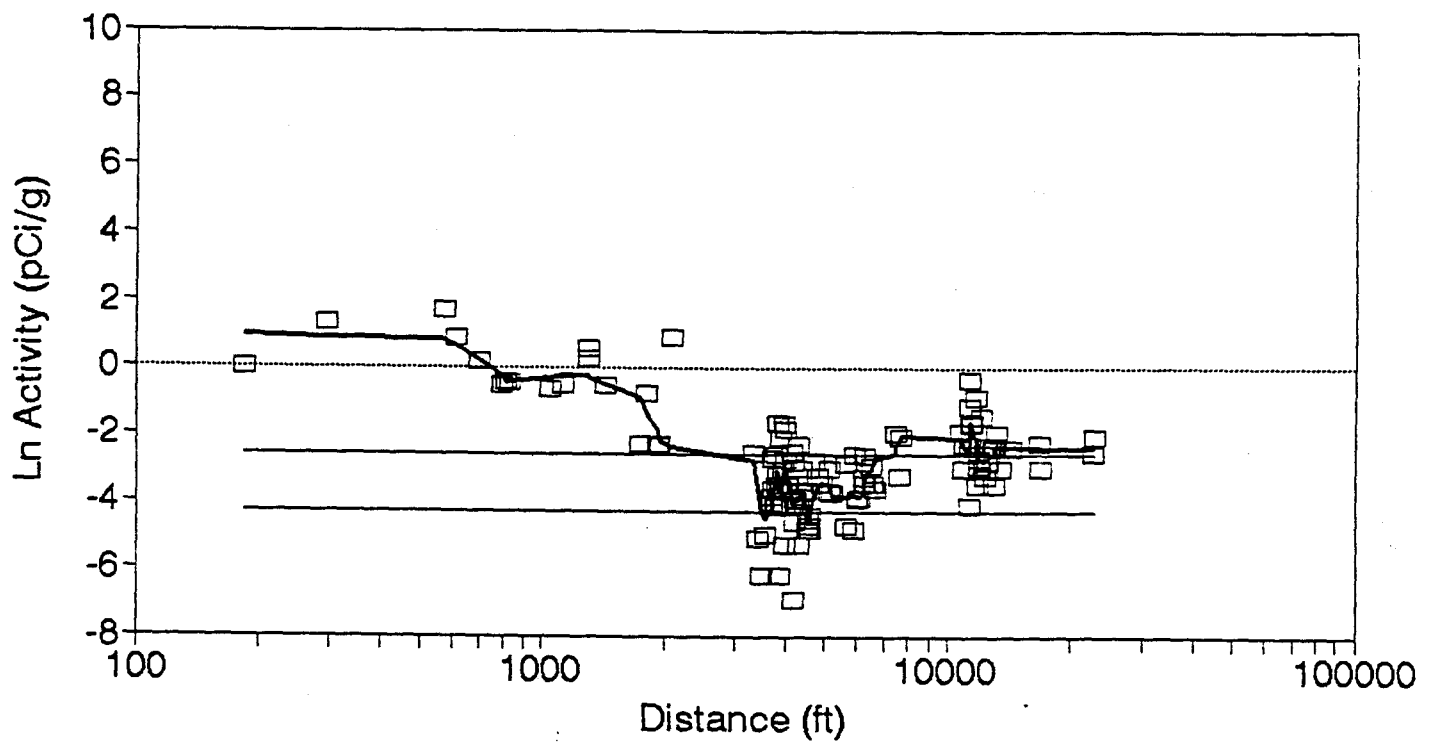
□ Data

— Median Smooth

— Lawton (1989)

PLUTONIUM-239/240

Sector 4



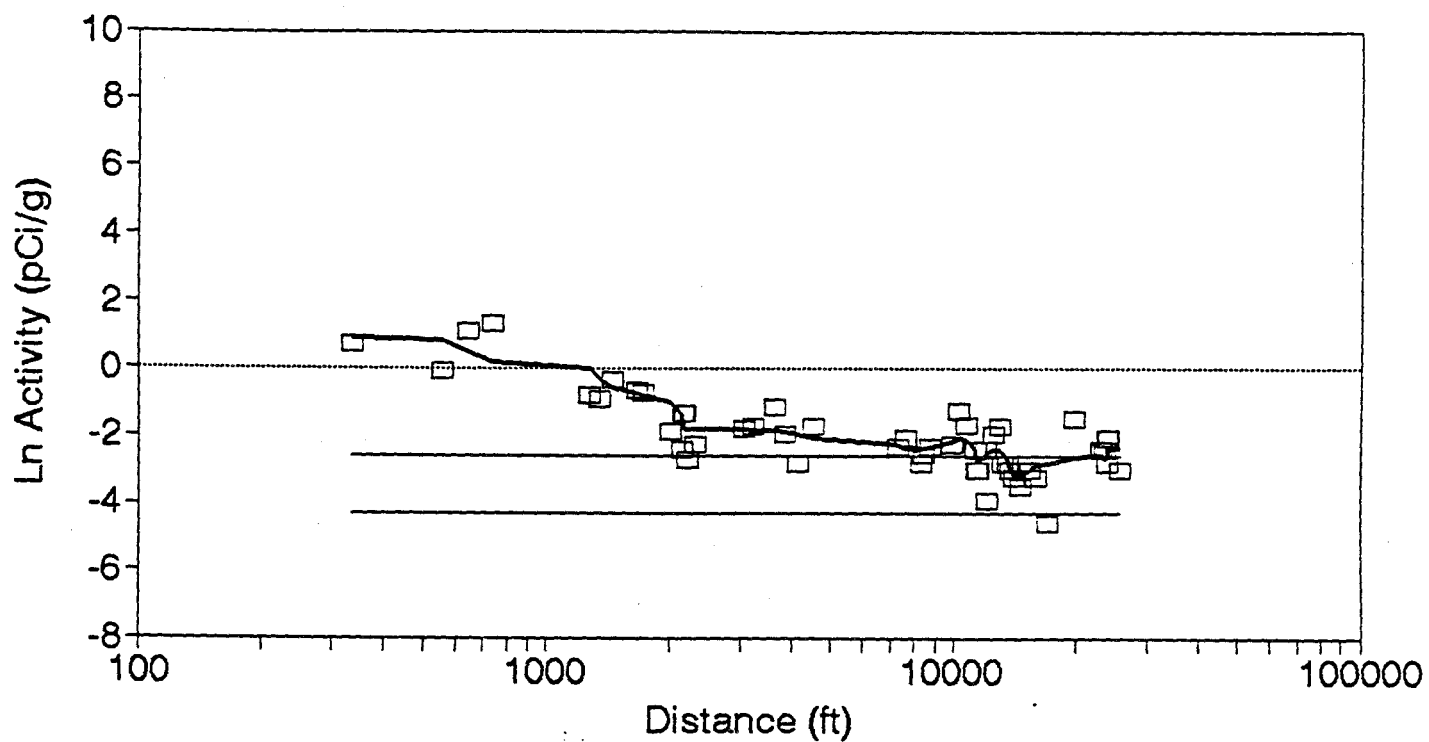
□ Data

— Median Smooth

— Lawton (1989)

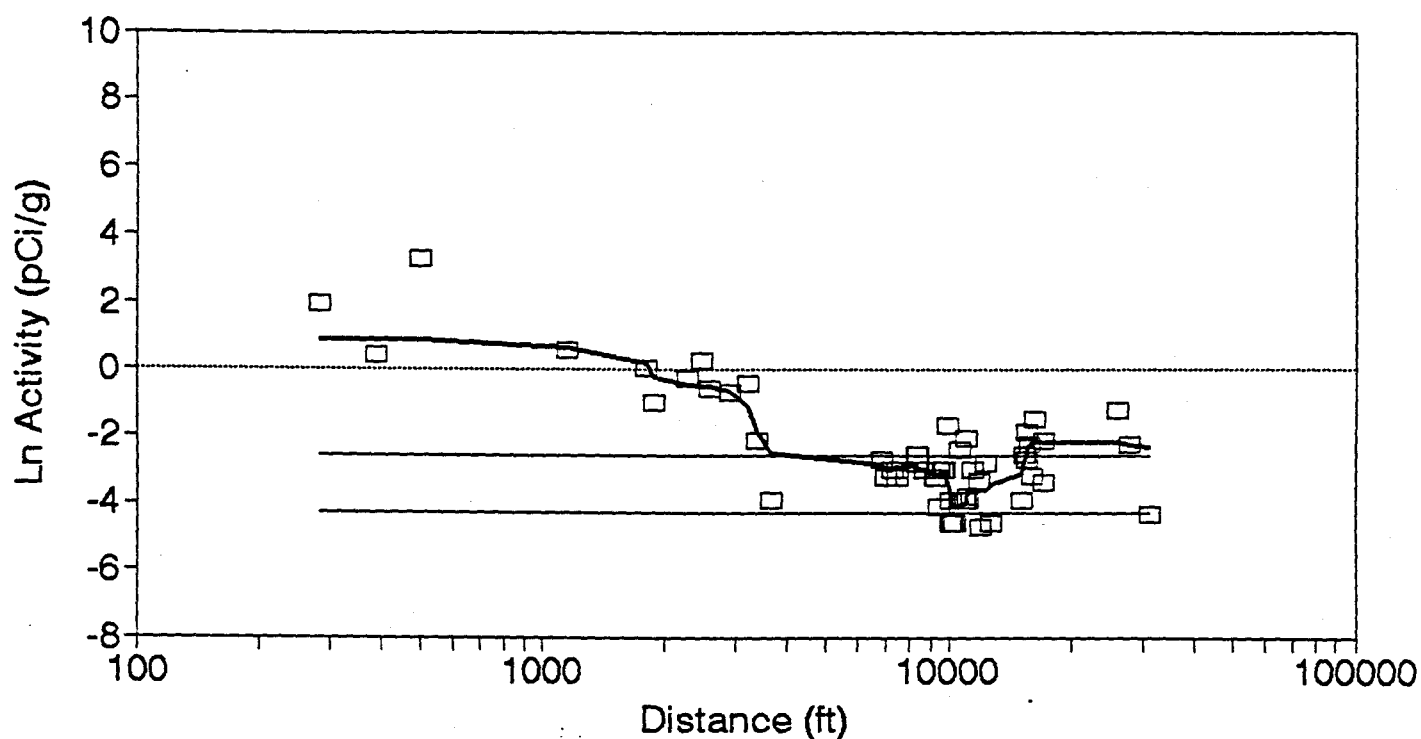
PLUTONIUM-239/240

Sector 5



PLUTONIUM-239/240

Sector 6



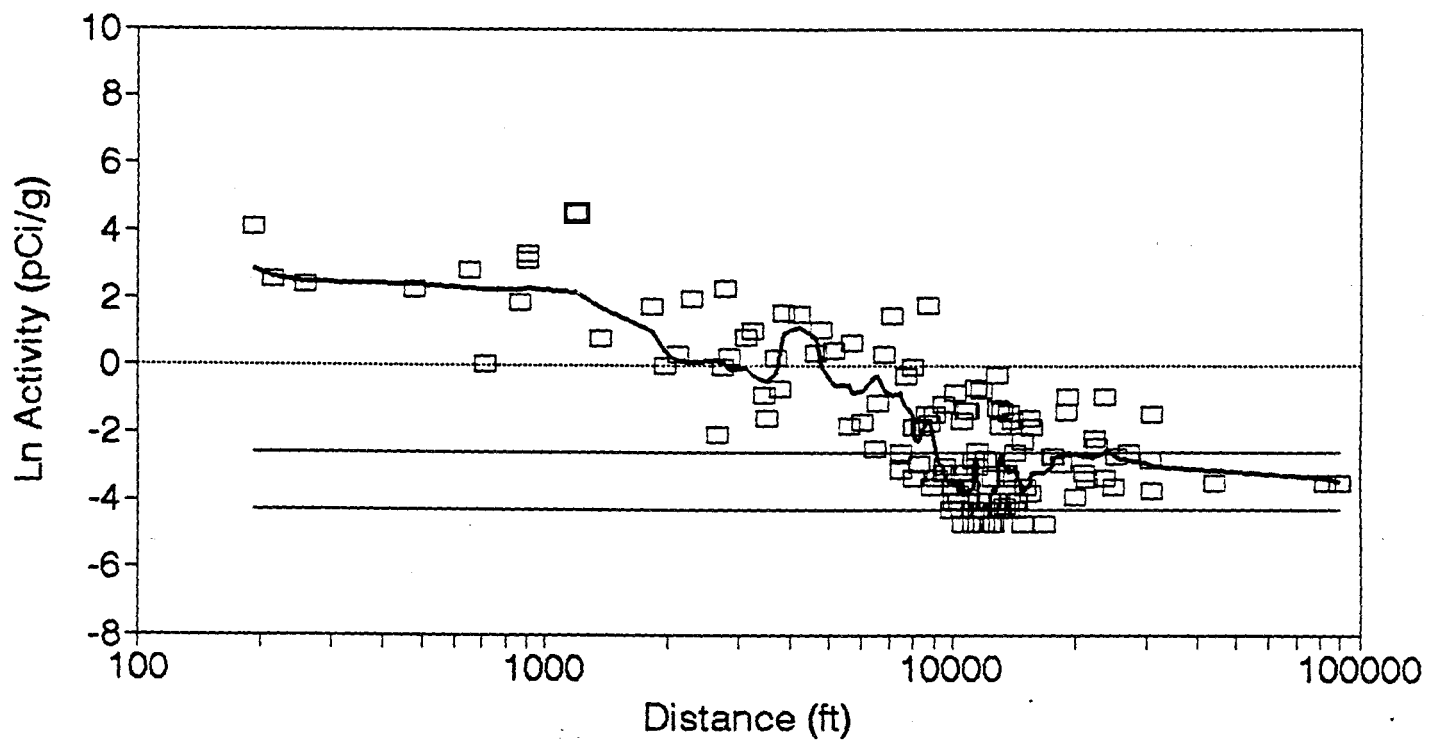
□ Data

— Median Smooth

— Lawton (1989)

PLUTONIUM-239/240

Sector 7



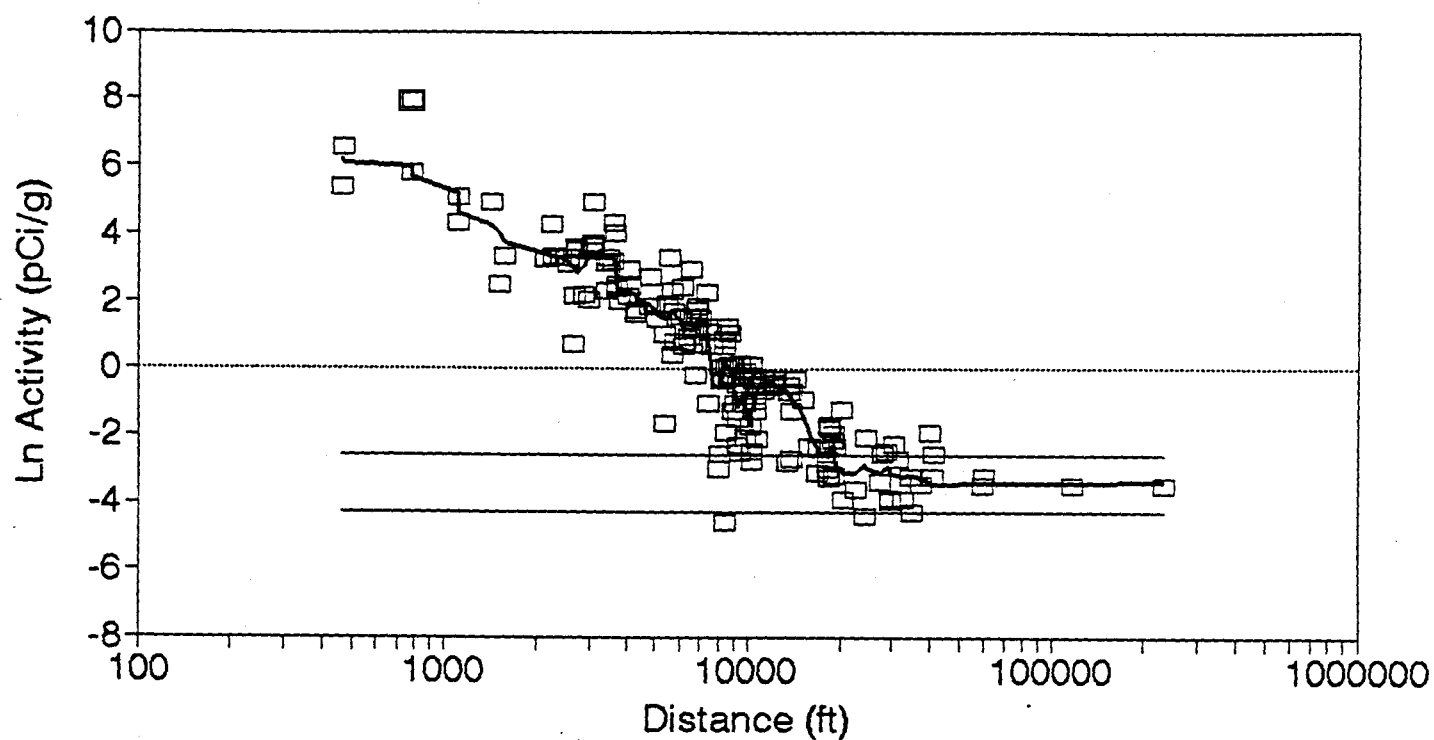
□ Data

— Median Smooth

— Lawton (1989)

PLUTONIUM-239/240

Sector 8

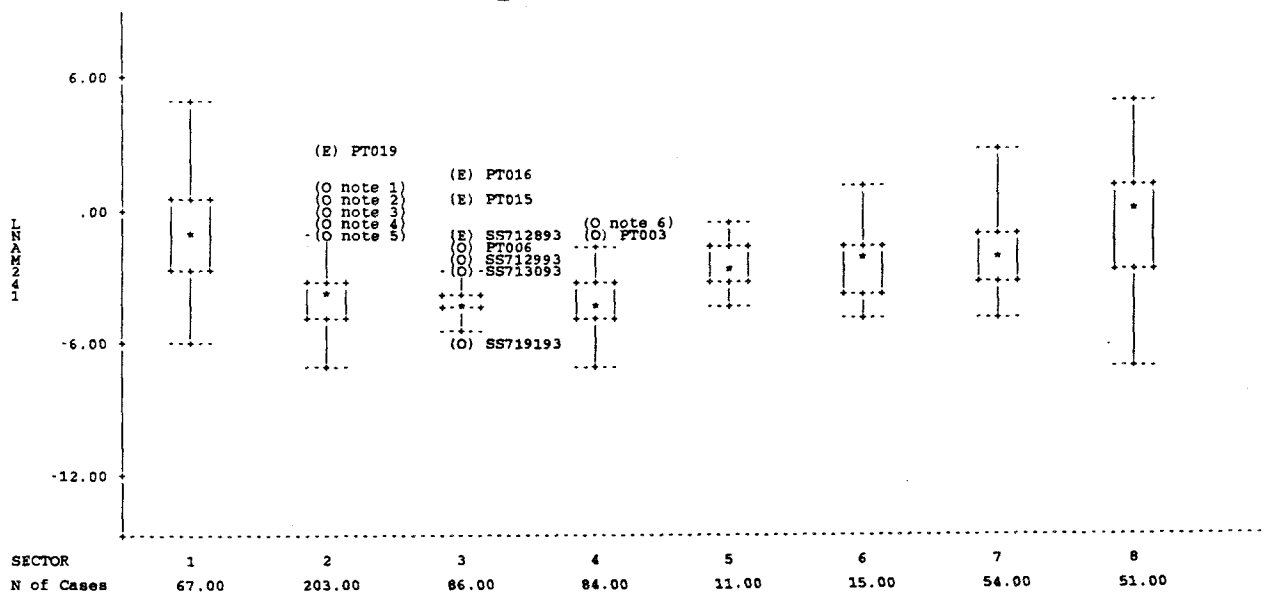


□ Data

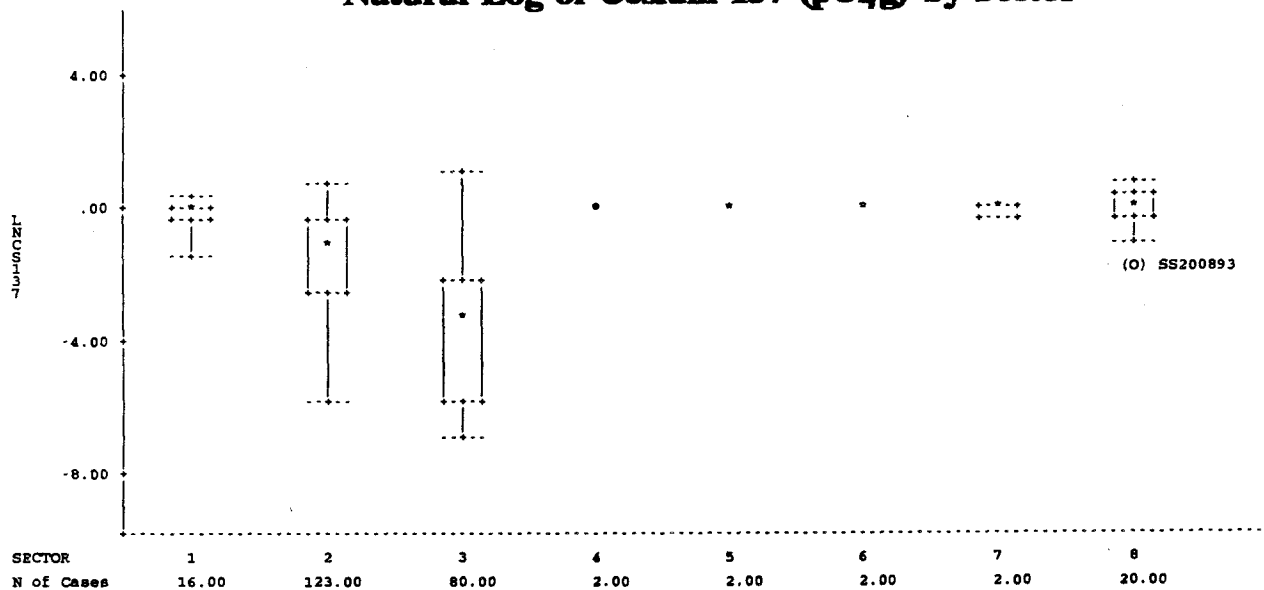
— Median Smooth

— Lawton (1989)

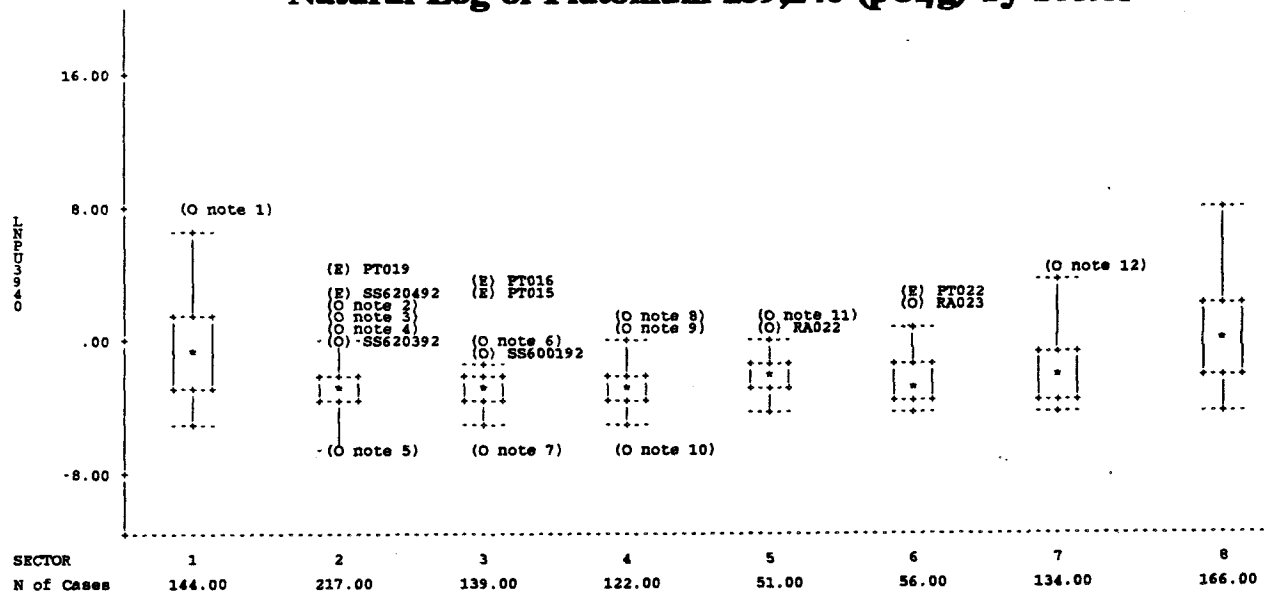
Natural Log of Americium-241 (pCi/g) by Sector



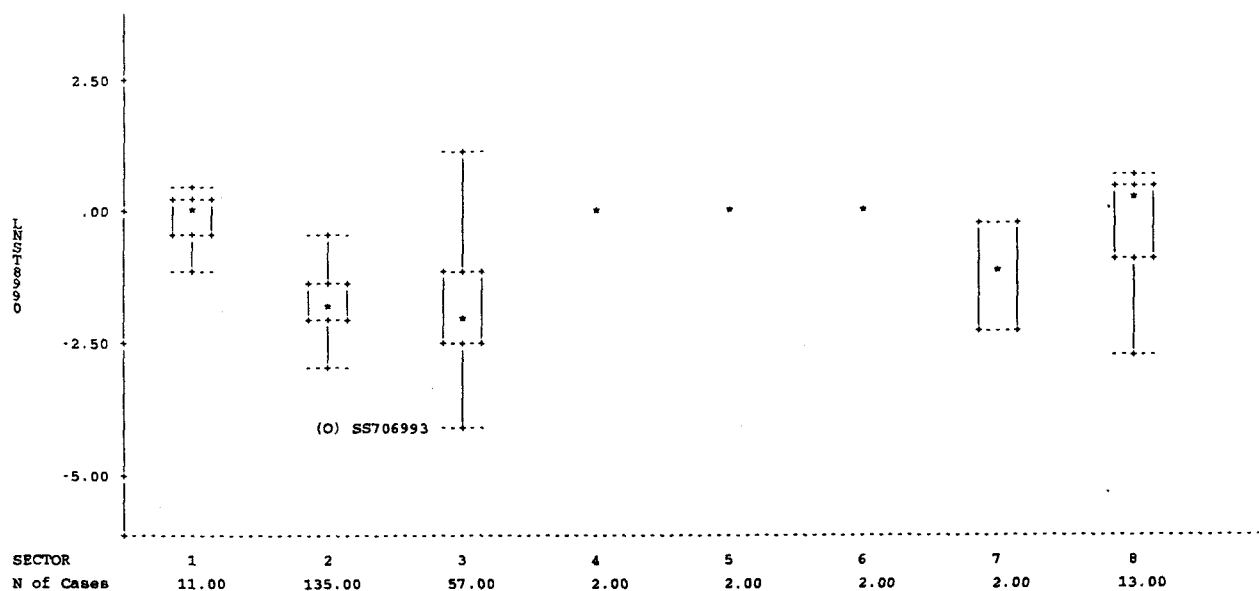
Natural Log of Cesium-137 (pCi/g) by Sector



Natural Log of Plutonium-239,240 (pCi/g) by Sector



Natural Log of Strontium-89,90 (pCi/g) by Sector

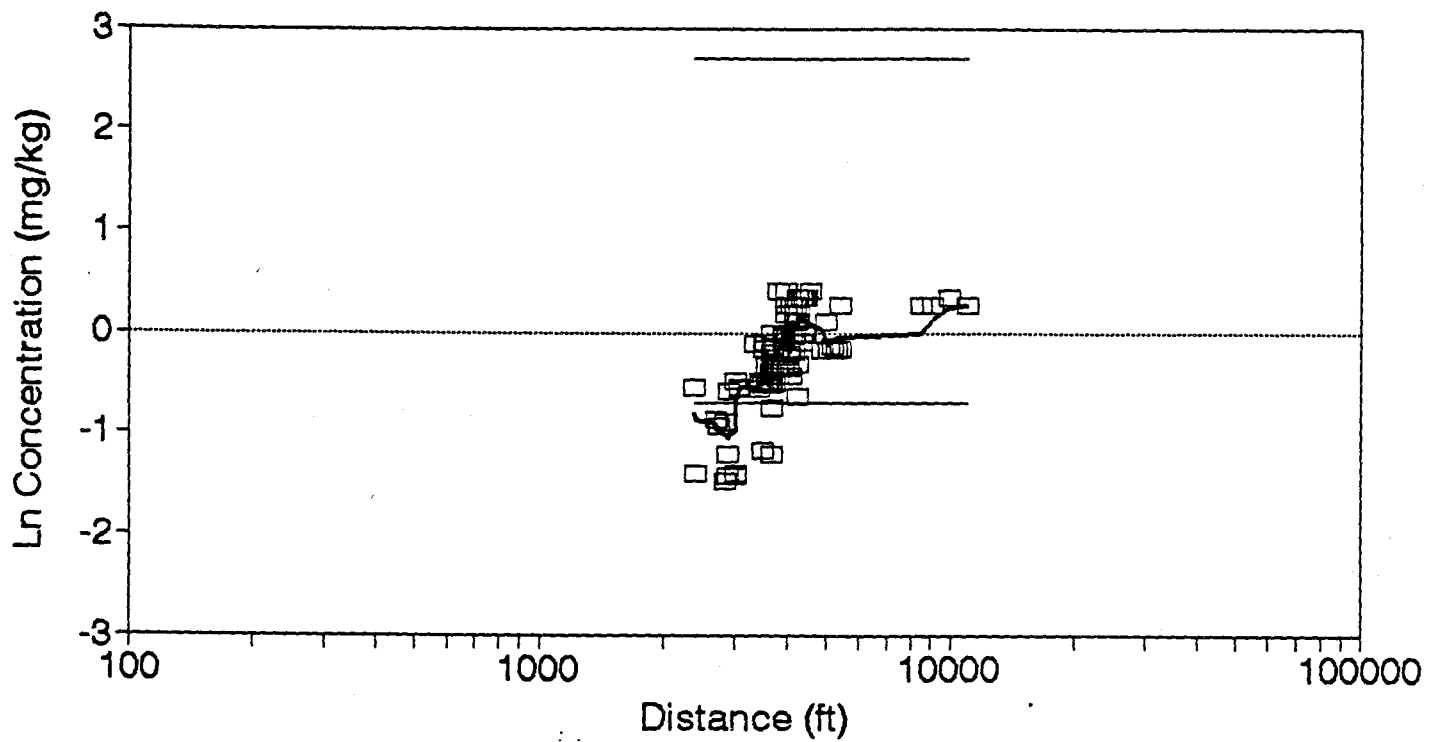


APPENDIX C

**EXPLORATORY DATA ANALYSIS RESULTS
METALS**

BERYLLIUM

Sector 1



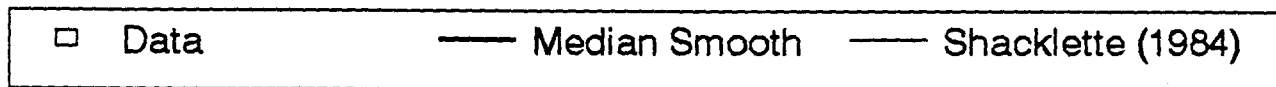
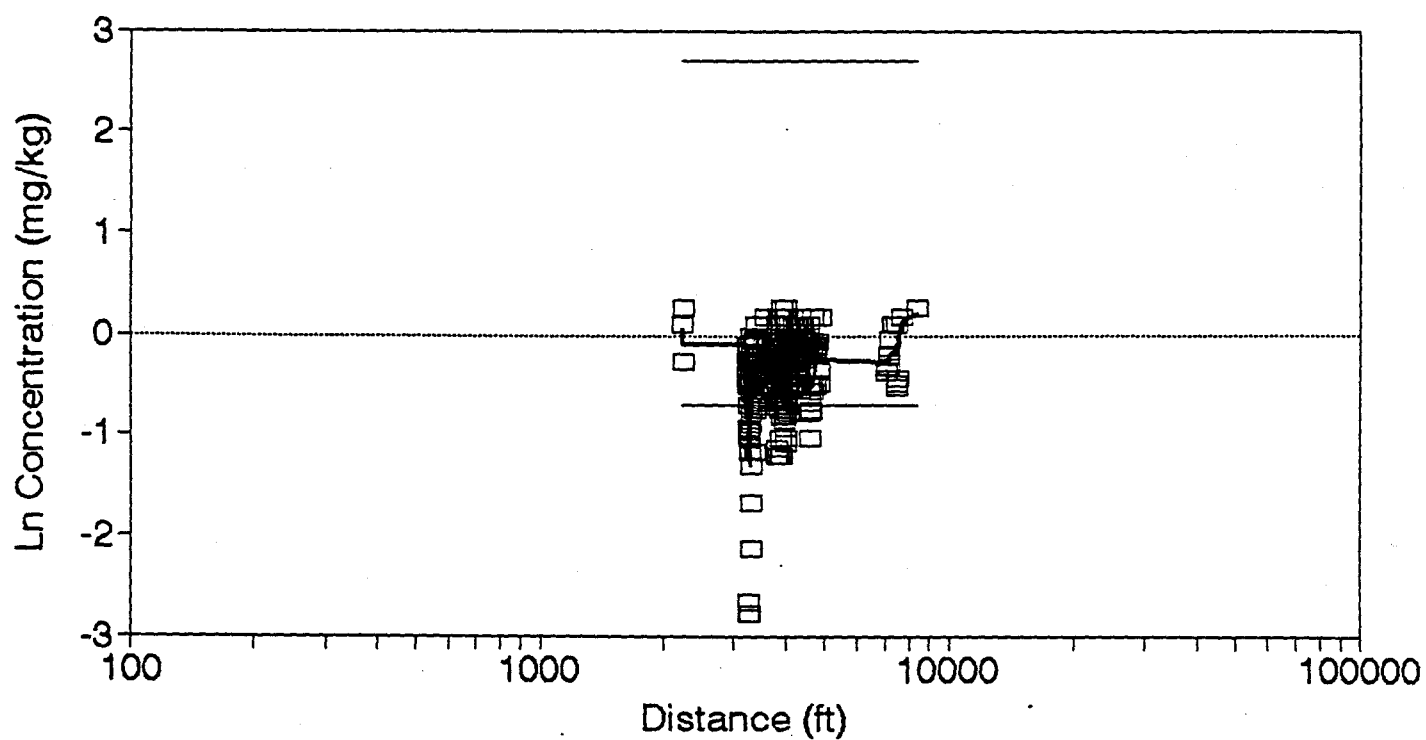
□ Data

— Median Smooth

— Shacklette (1984)

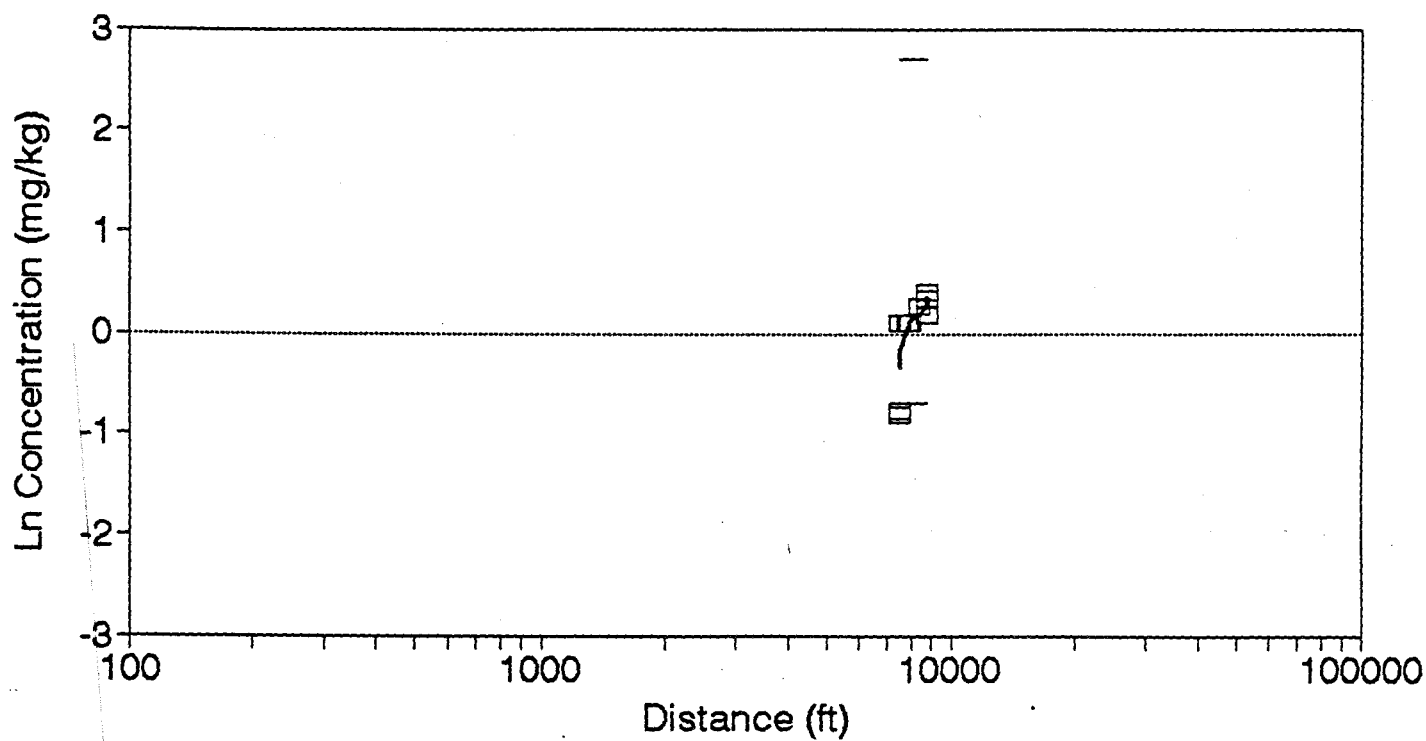
BERYLLIUM

Sector 2



BERYLLIUM

Sector 3



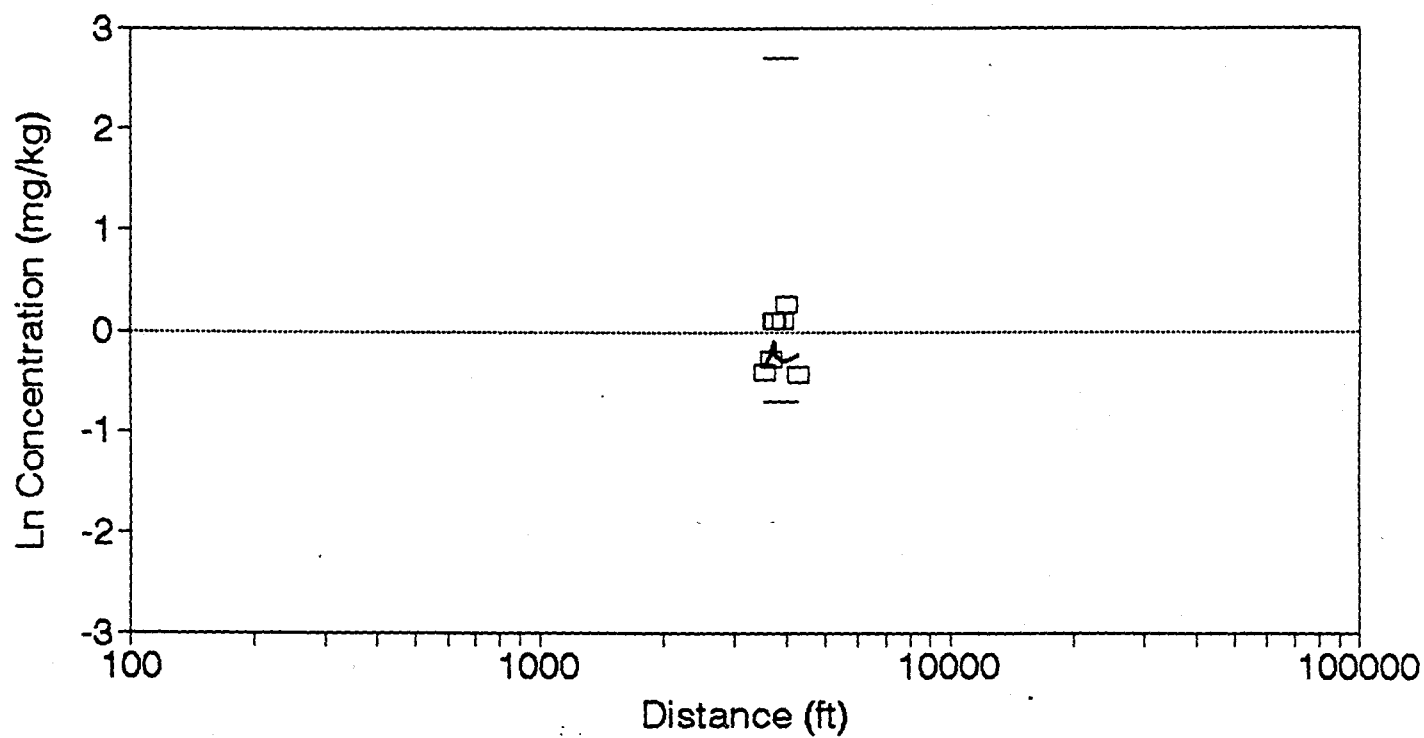
□ Data

— Median Smooth

— Shacklette (1984)

BERYLLIUM

Sector 4



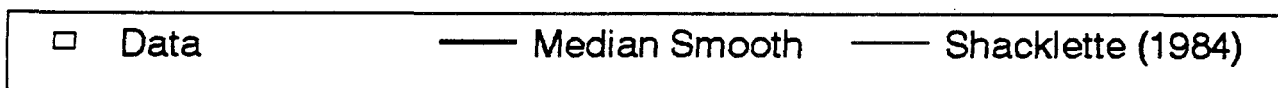
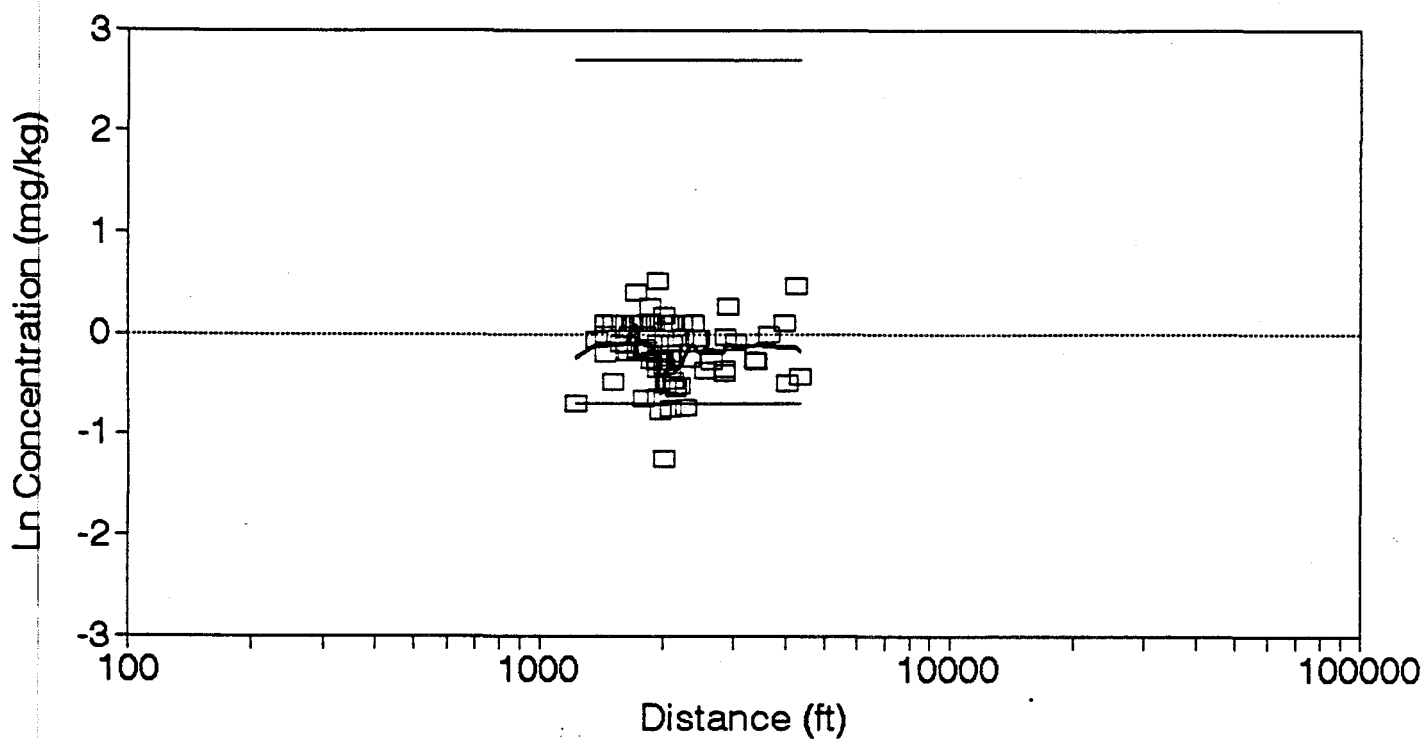
□ Data

— Median Smooth

— Shacklette (1984)

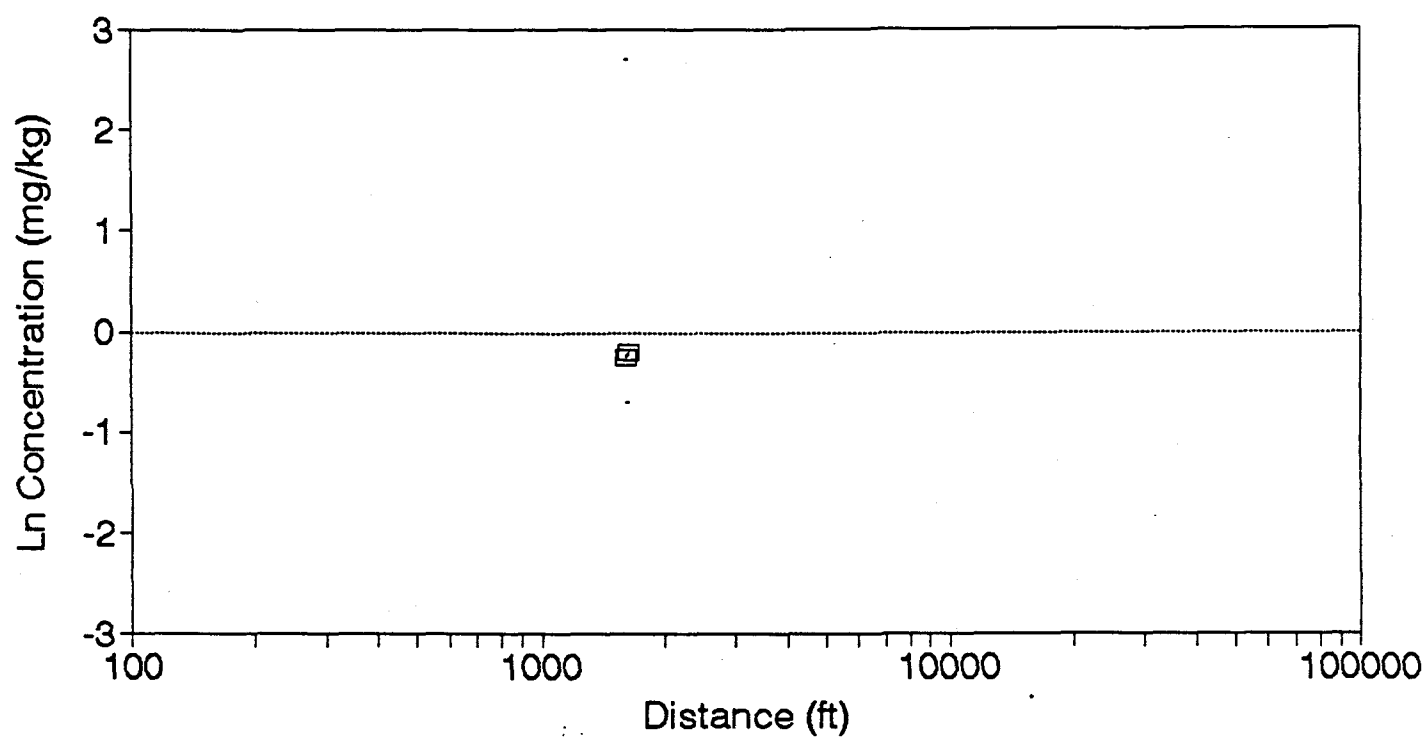
BERYLLIUM

Sector 5



BERYLLIUM

Sector 6



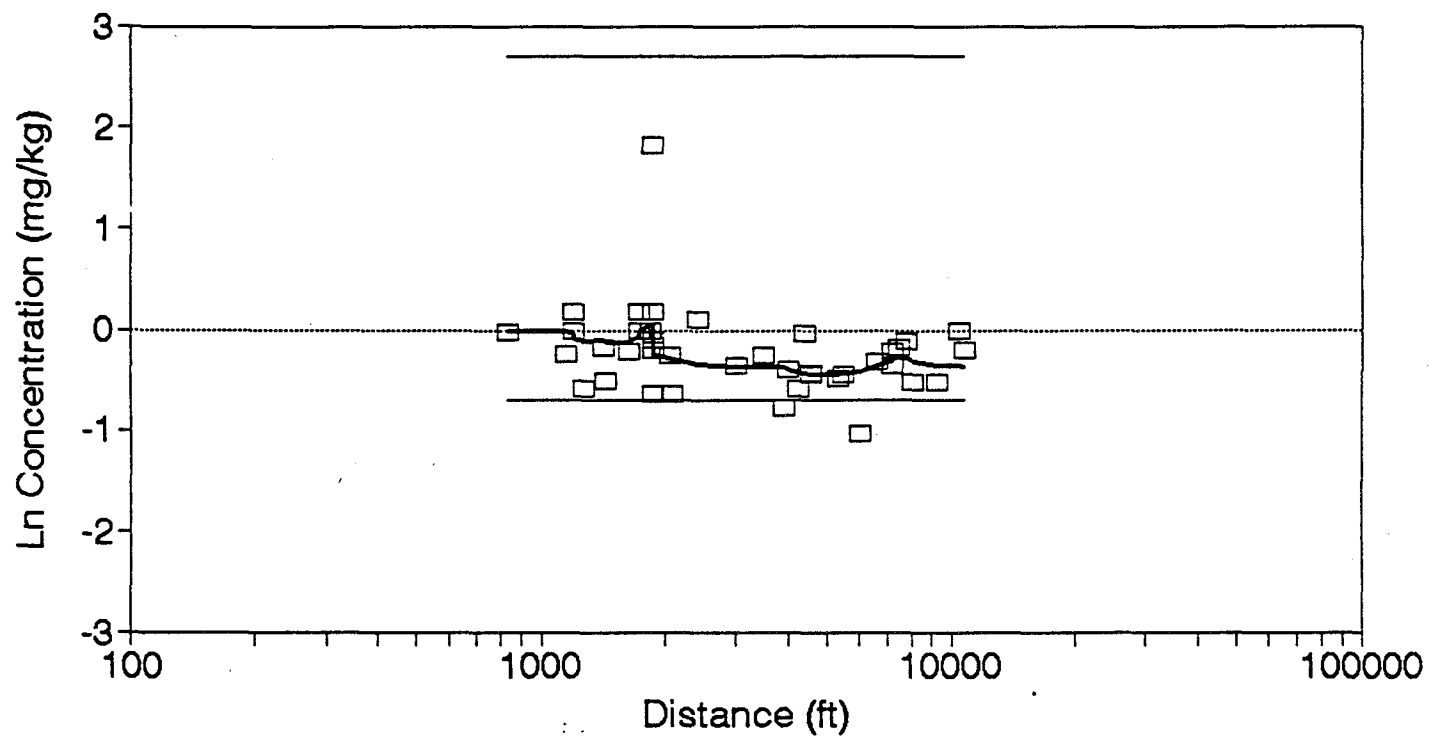
□ Data

— Median Smooth

— Shacklette (1984)

BERYLLIUM

Sector 7



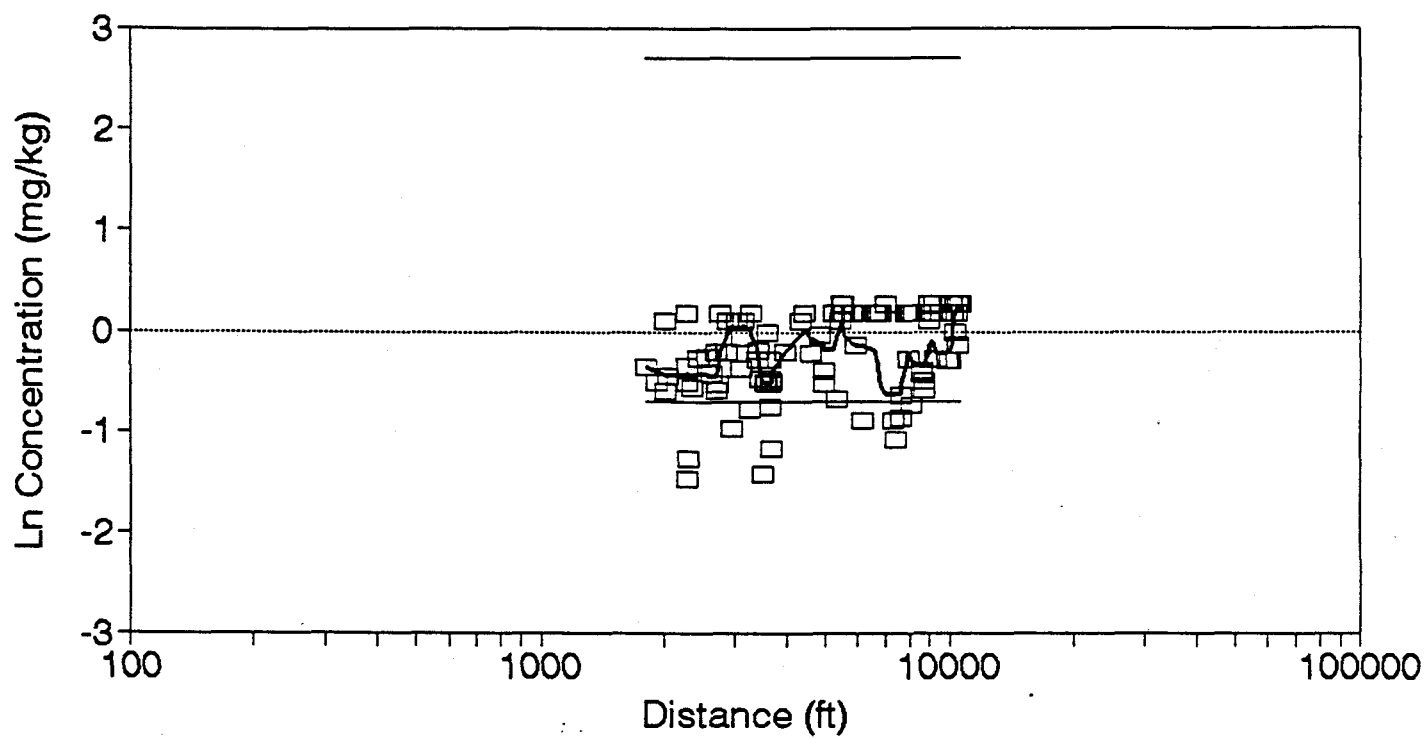
□ Data

— Median Smooth

— Shackle (1984)

BERYLLIUM

Sector 8



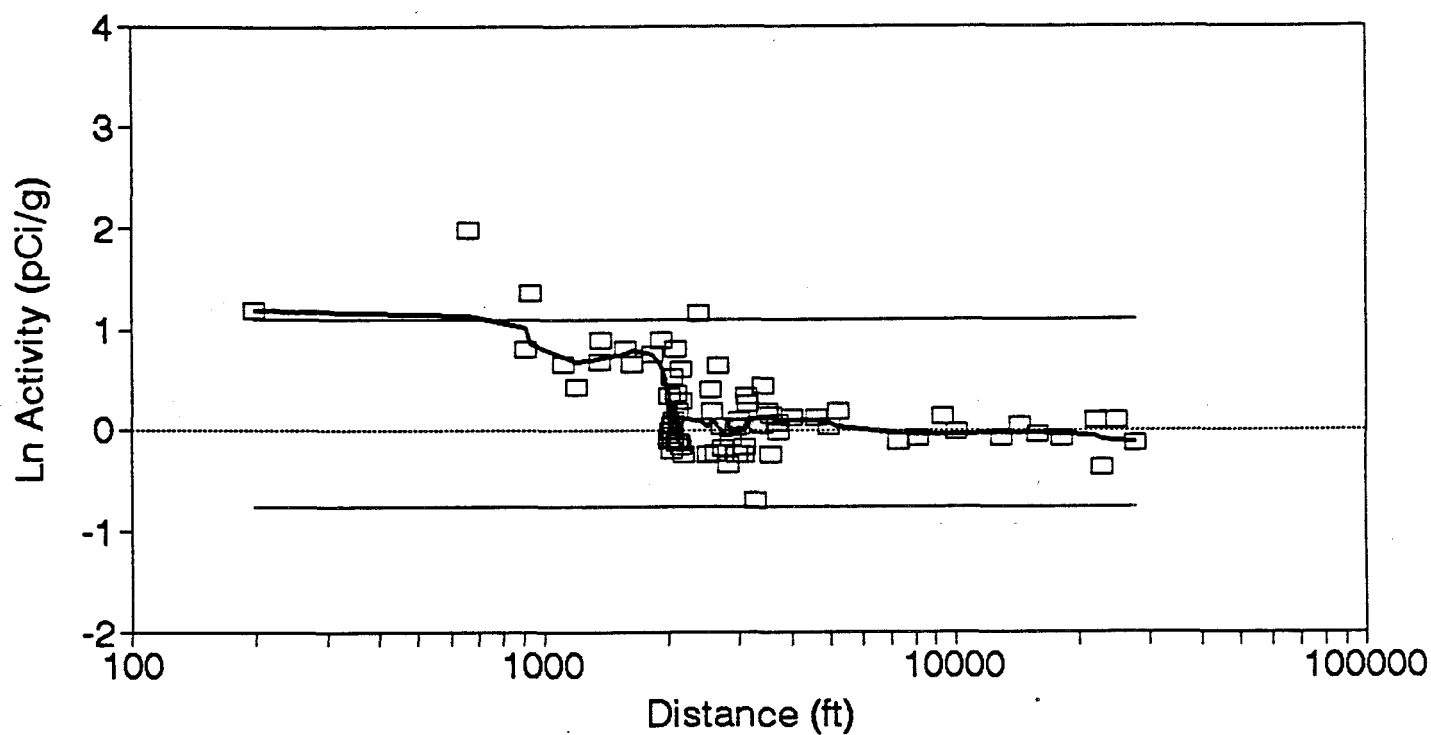
□ Data

— Median Smooth

— Shacklette (1984)

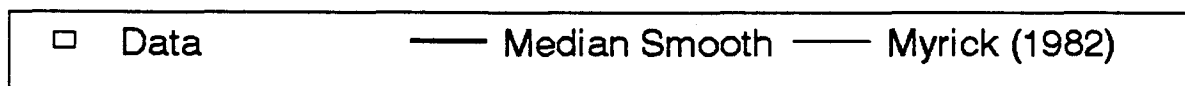
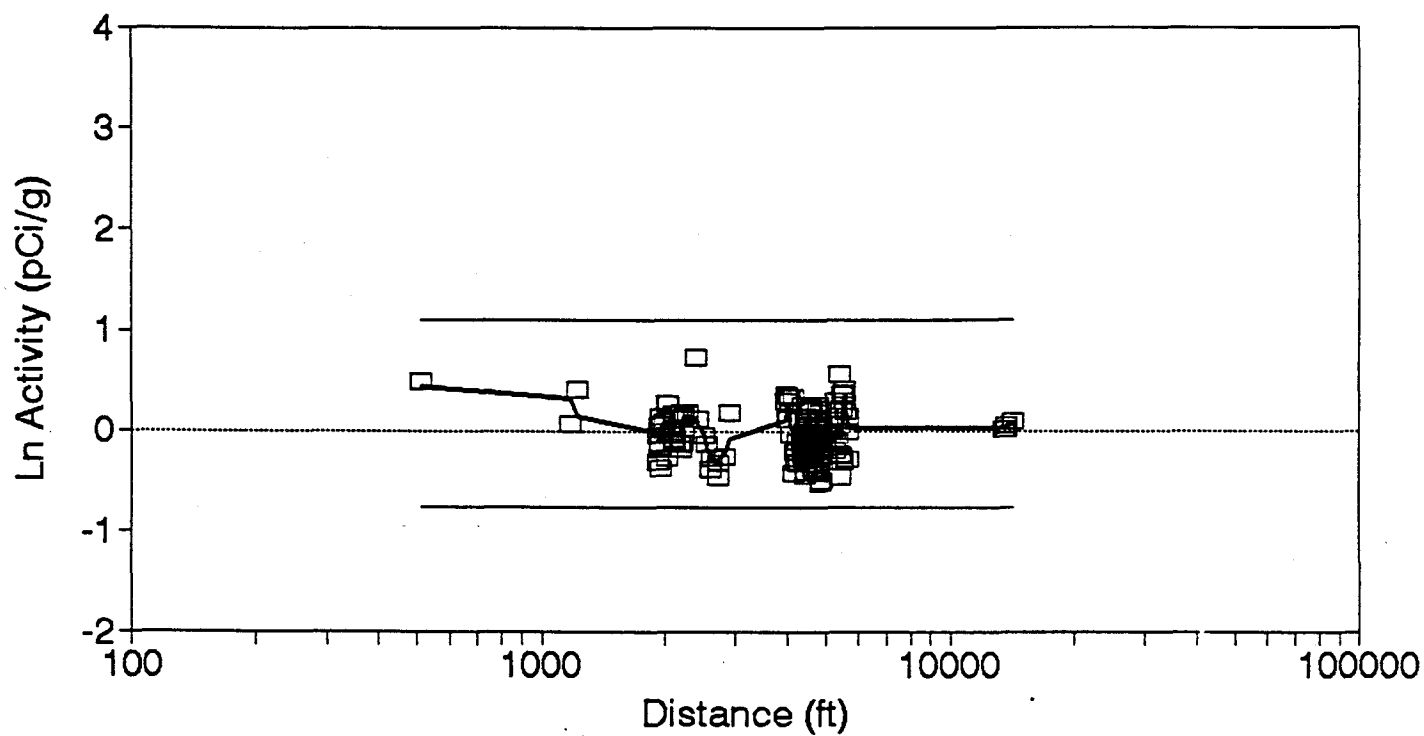
URANIUM-238

Sector 1



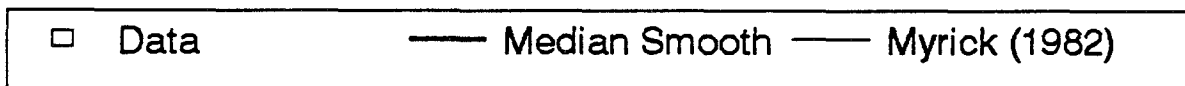
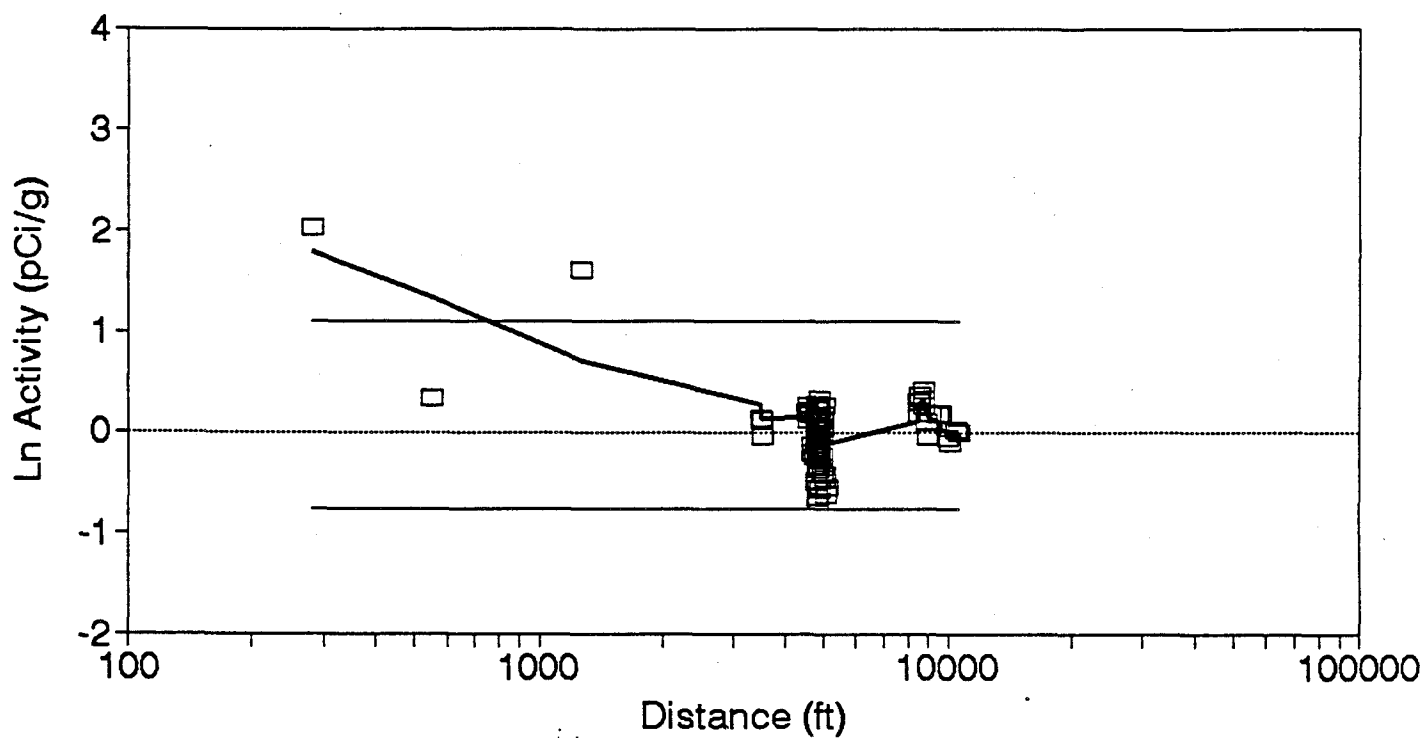
URANIUM-238

Sector 2



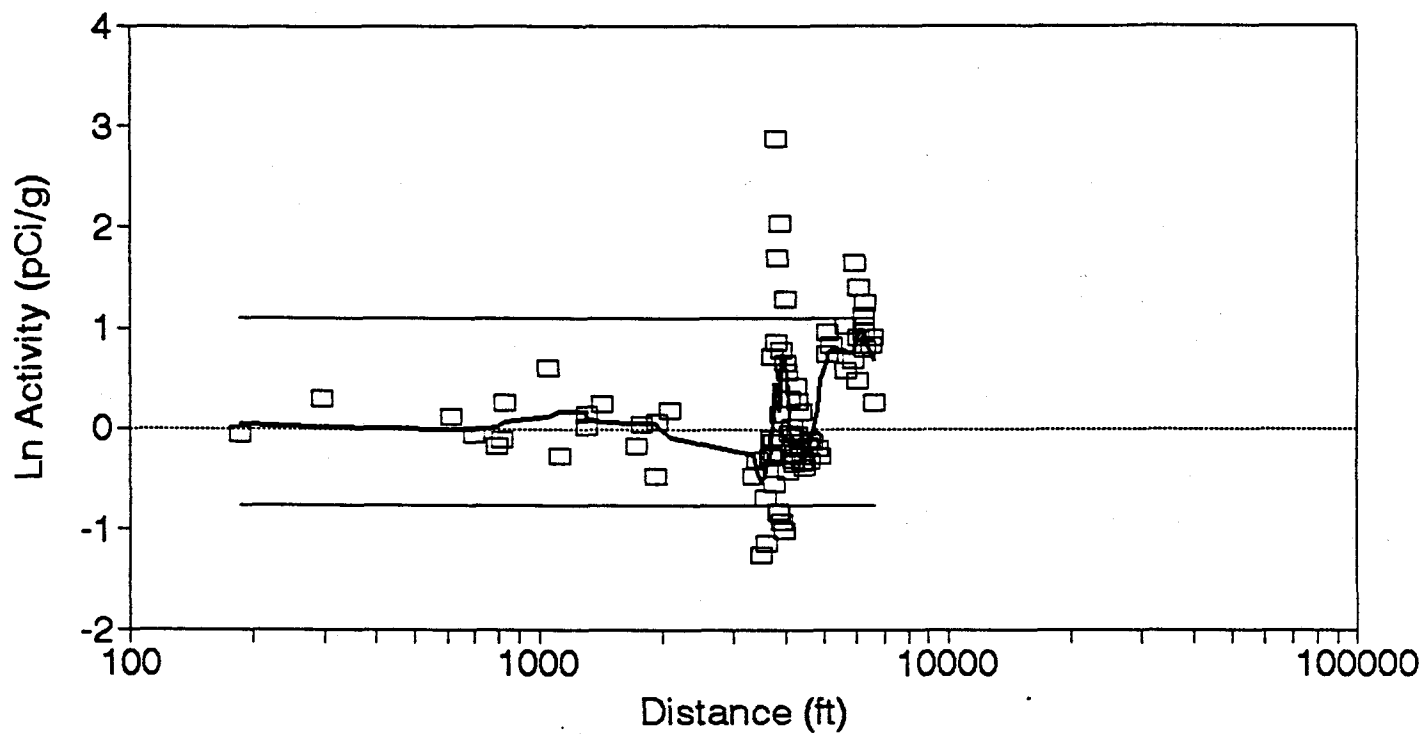
URANIUM-238

Sector 3



URANIUM-238

Sector 4



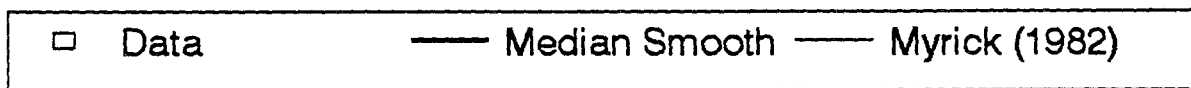
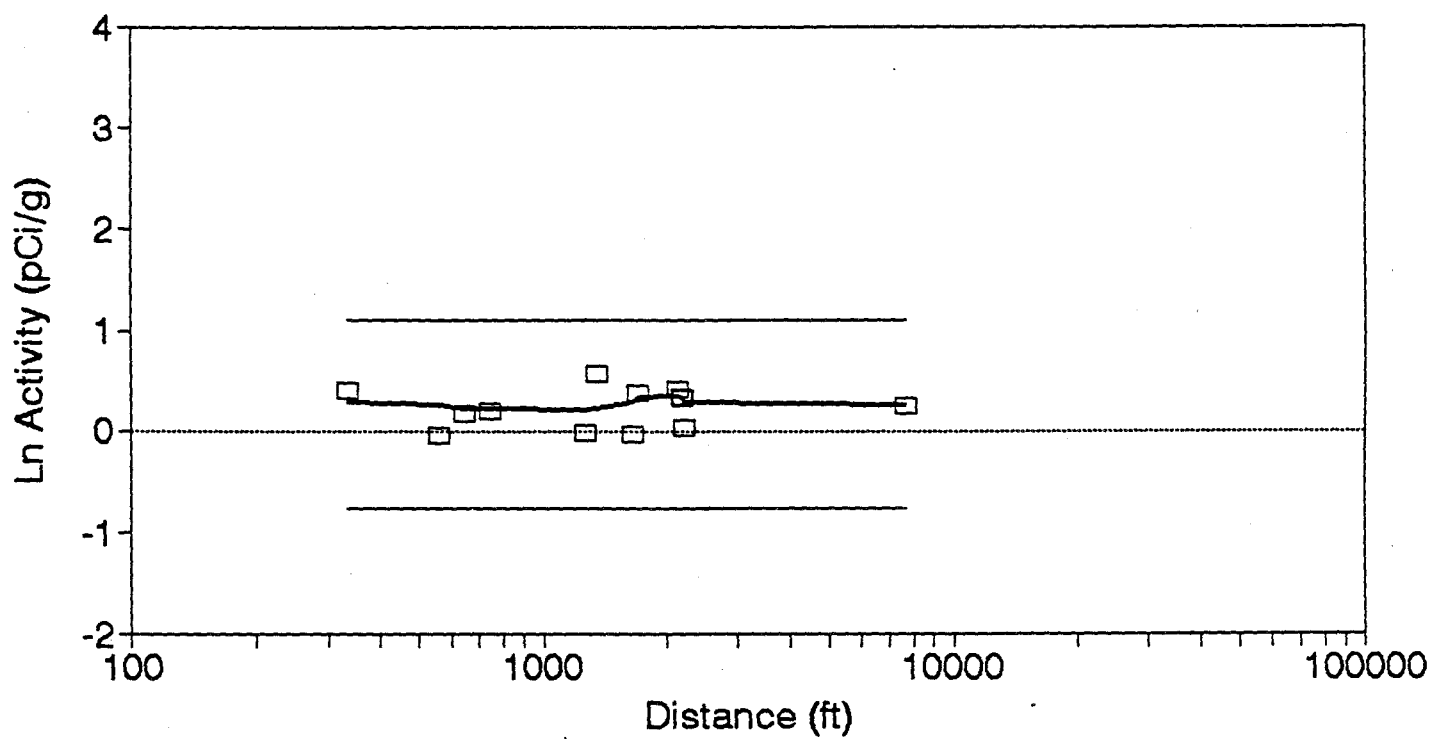
□ Data

— Median Smooth

— Myrick (1982)

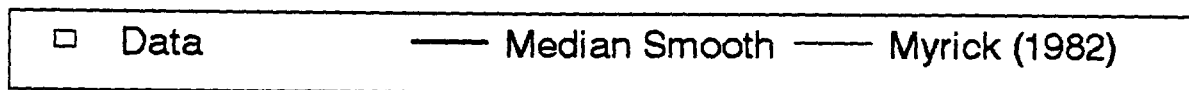
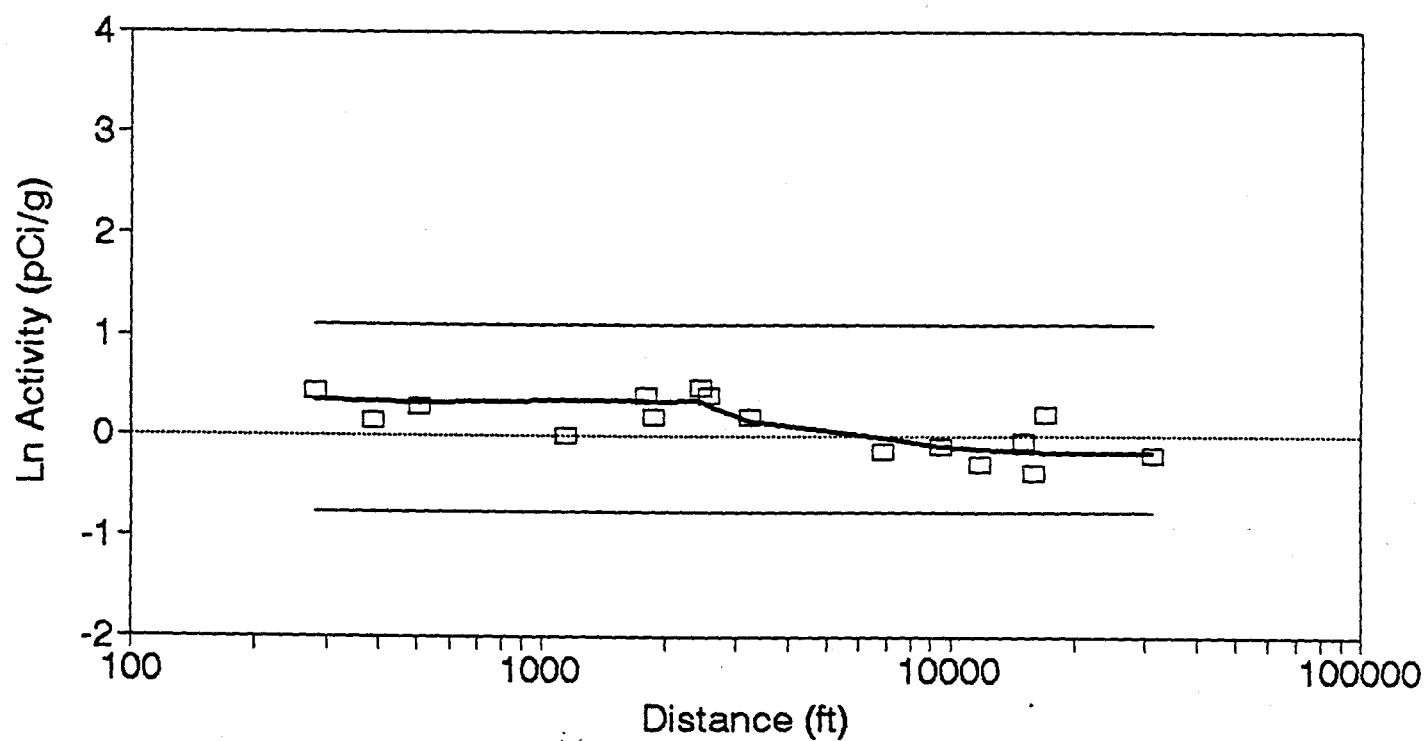
URANIUM-238

Sector 5



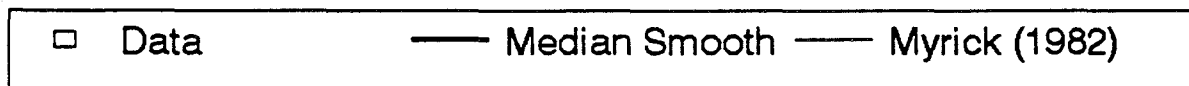
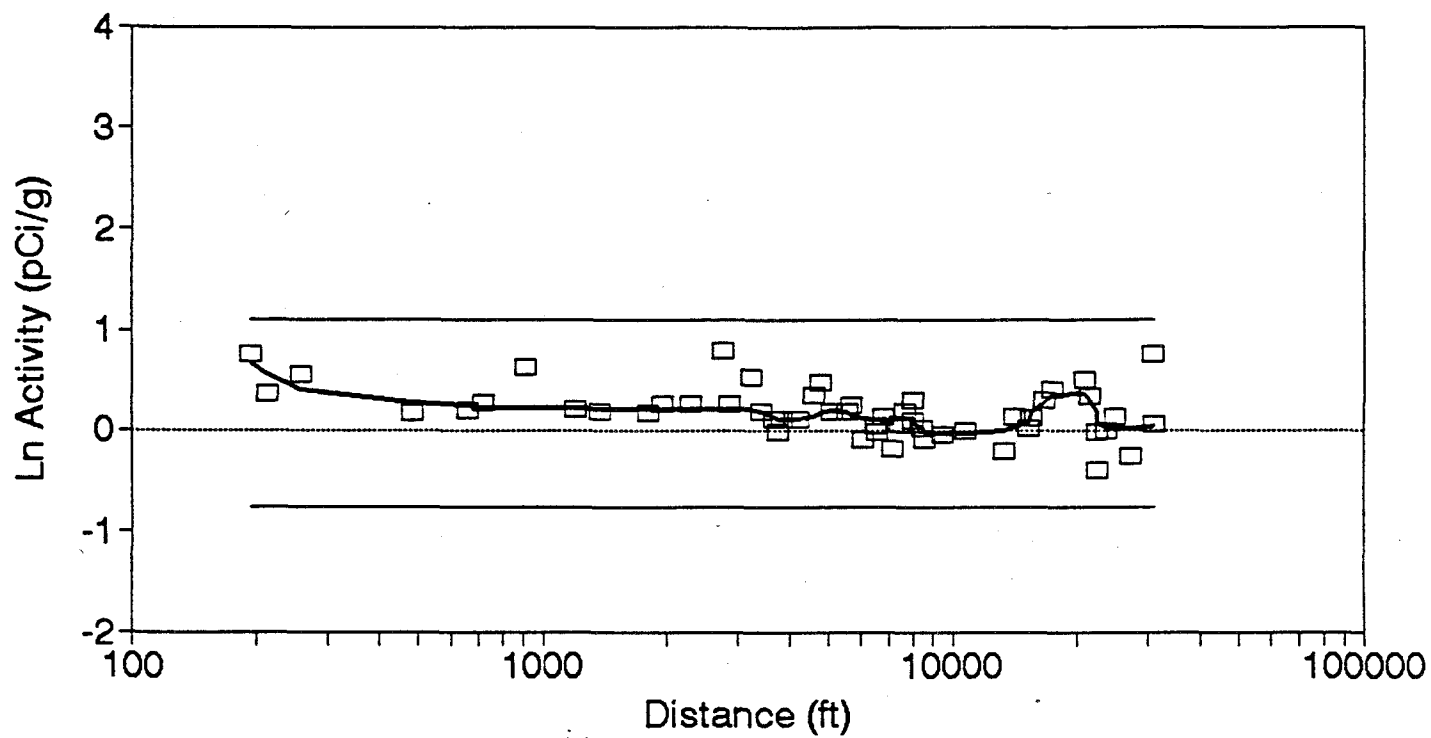
URANIUM-238

Sector 6



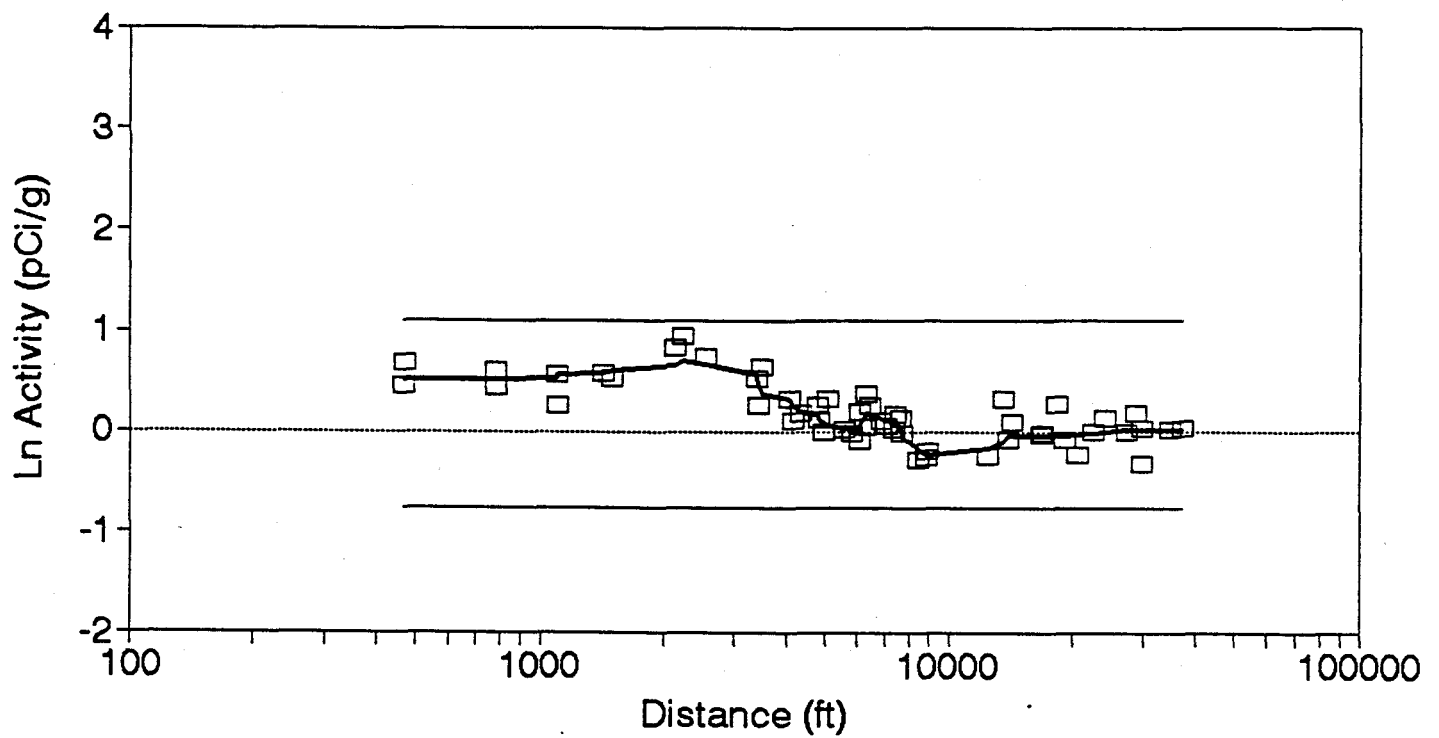
URANIUM-238

Sector 7

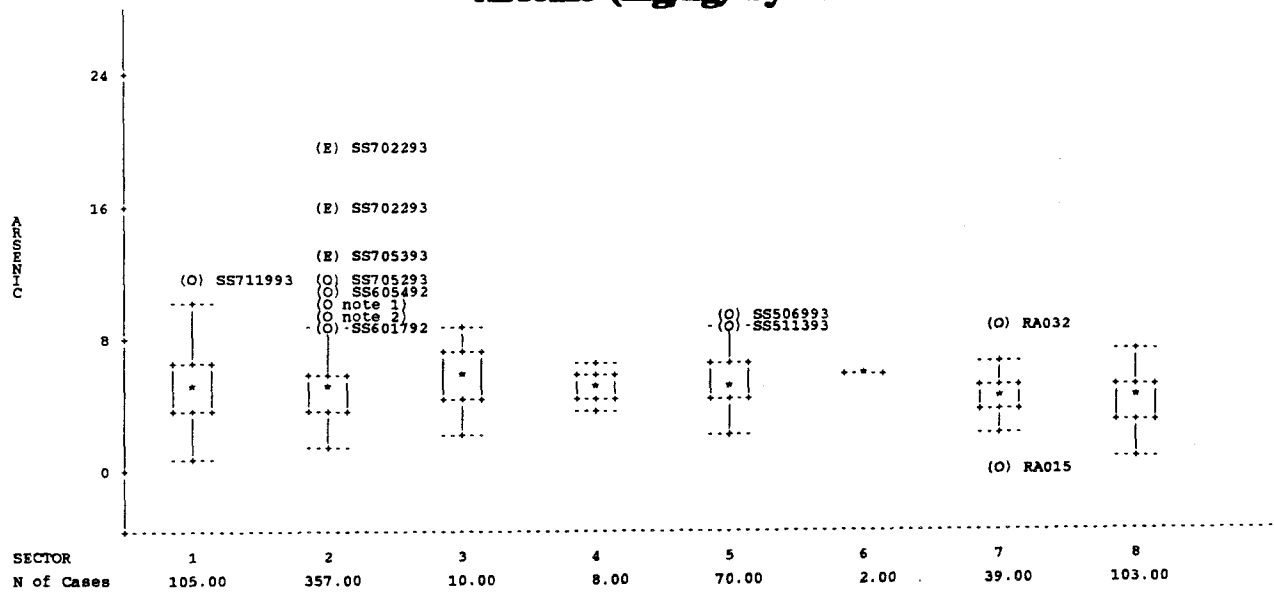


URANIUM-238

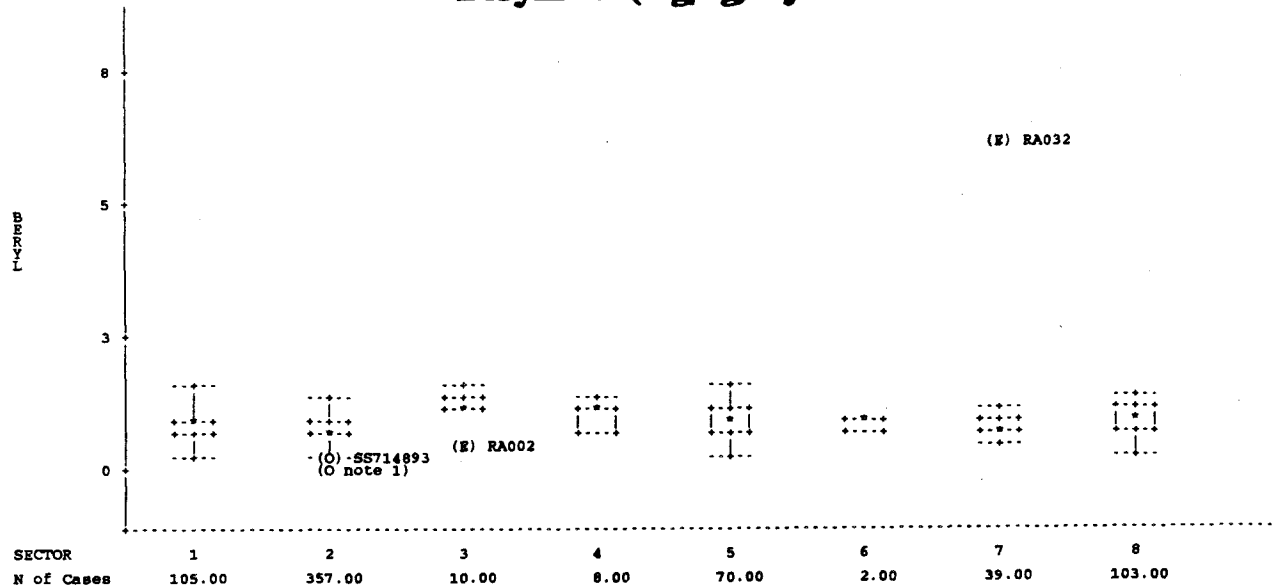
Sector 8



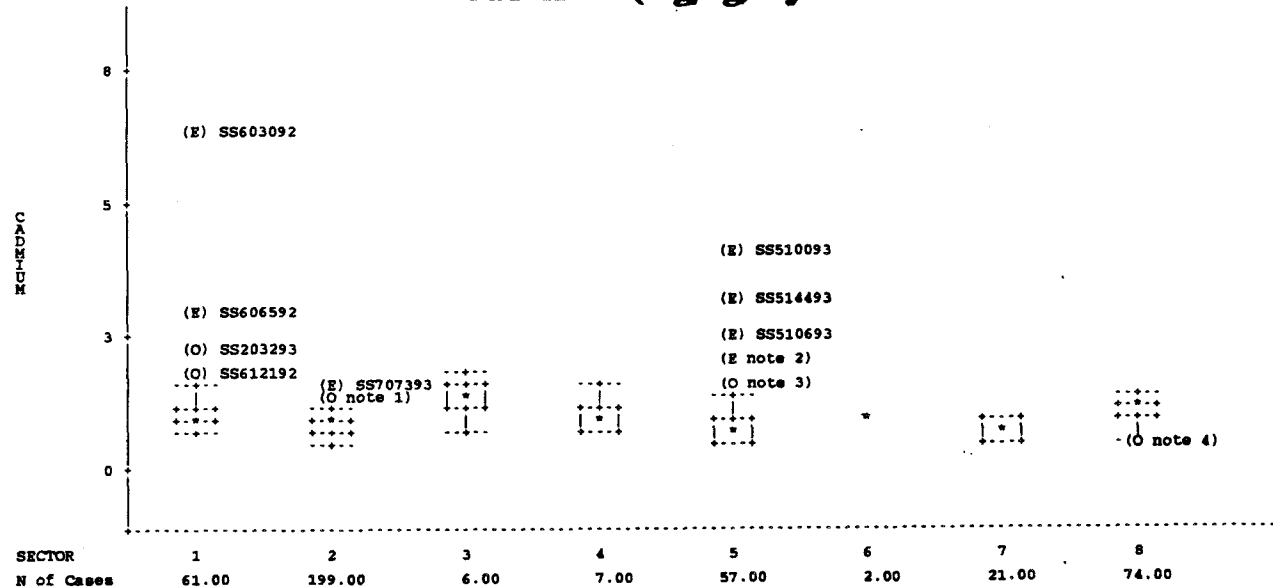
Arsenic (mg/kg) by Sector



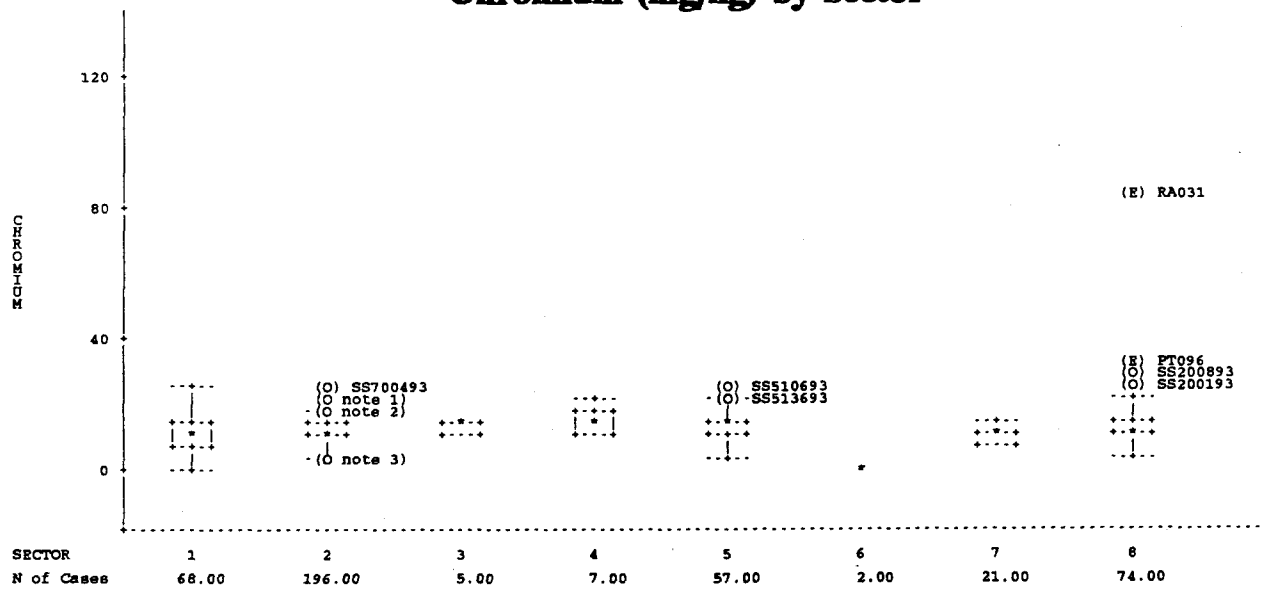
Beryllium (mg/kg) by Sector



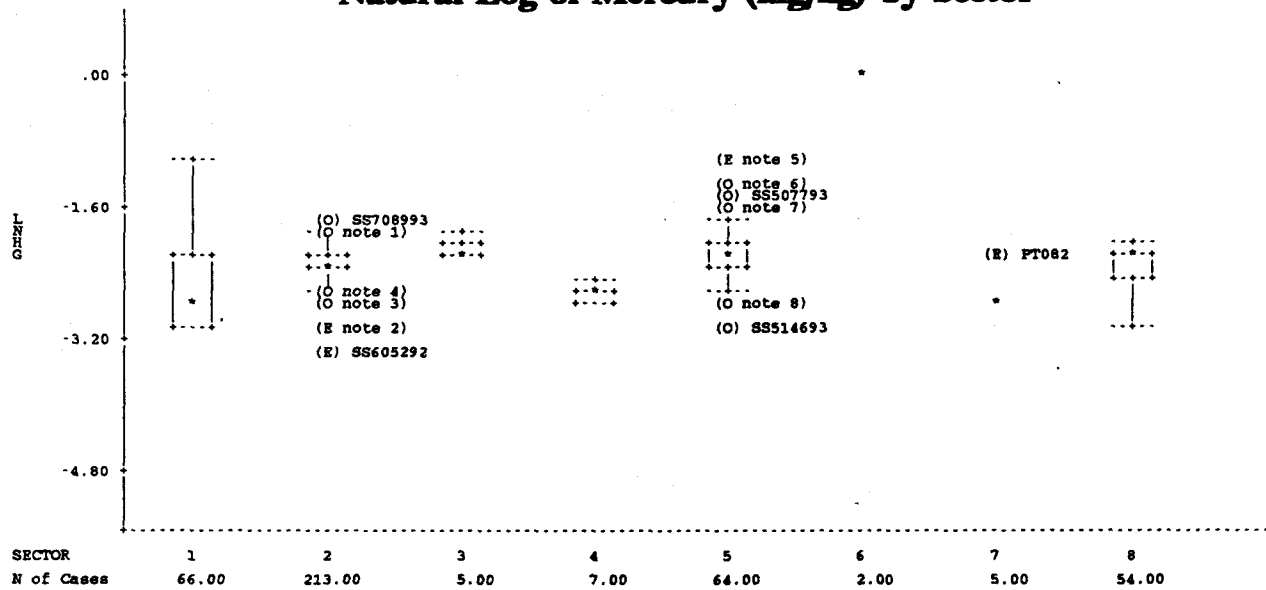
Cadmium (mg/kg) by Sector



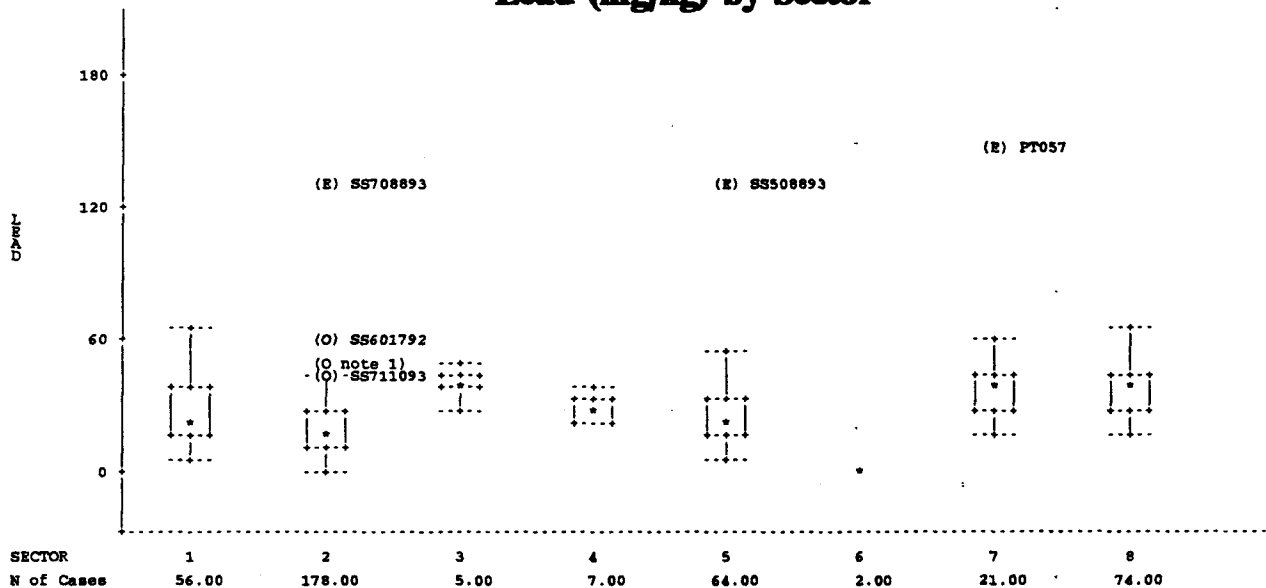
Chromium (mg/kg) by Sector



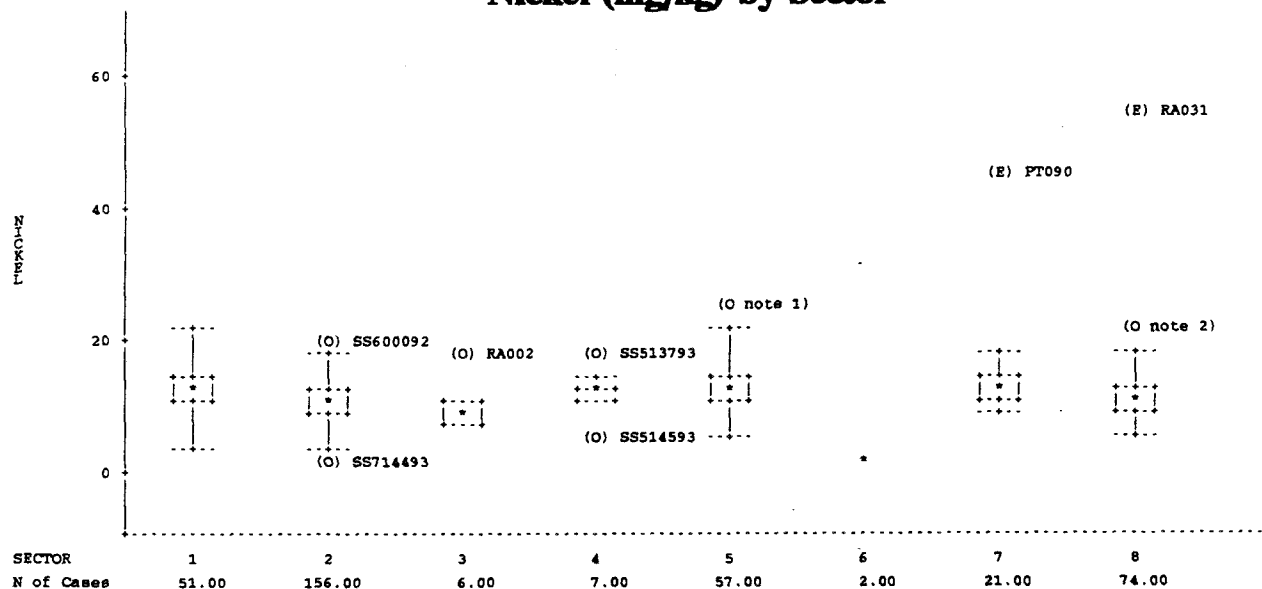
Natural Log of Mercury (mg/kg) by Sector



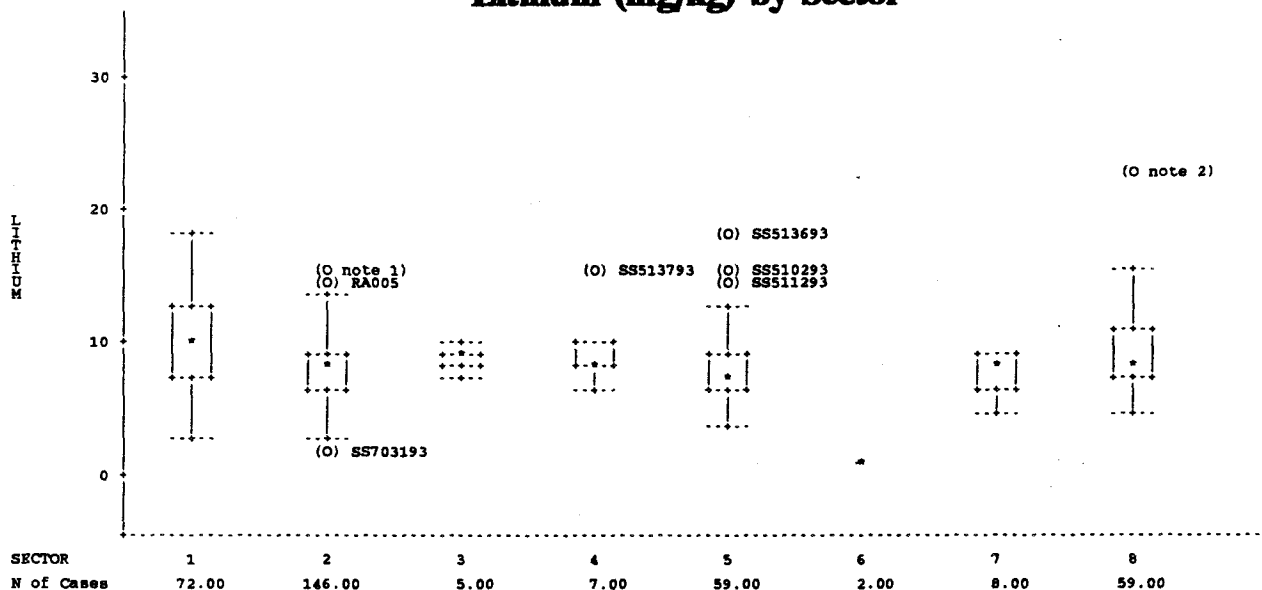
Lead (mg/kg) by Sector



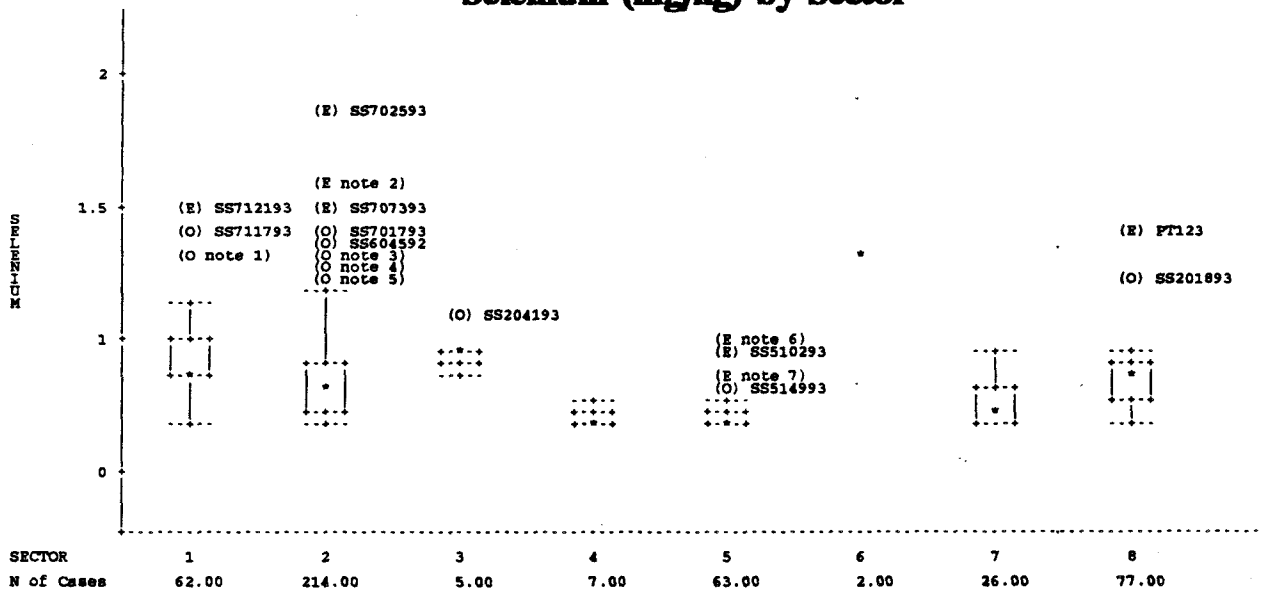
Nickel (mg/kg) by Sector



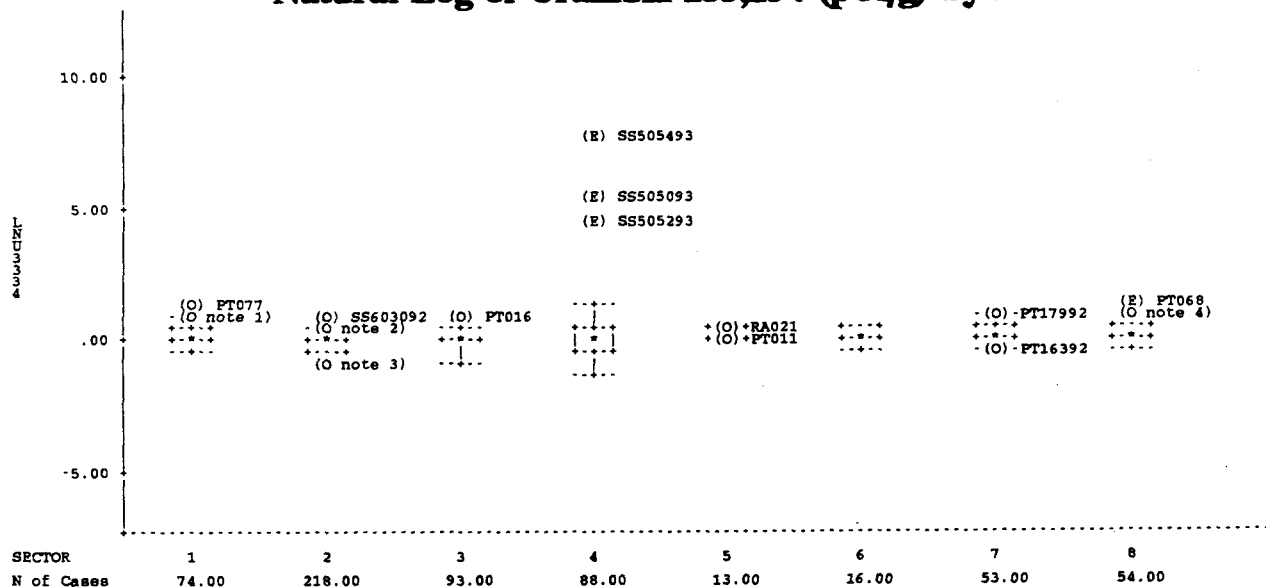
Lithium (mg/kg) by Sector



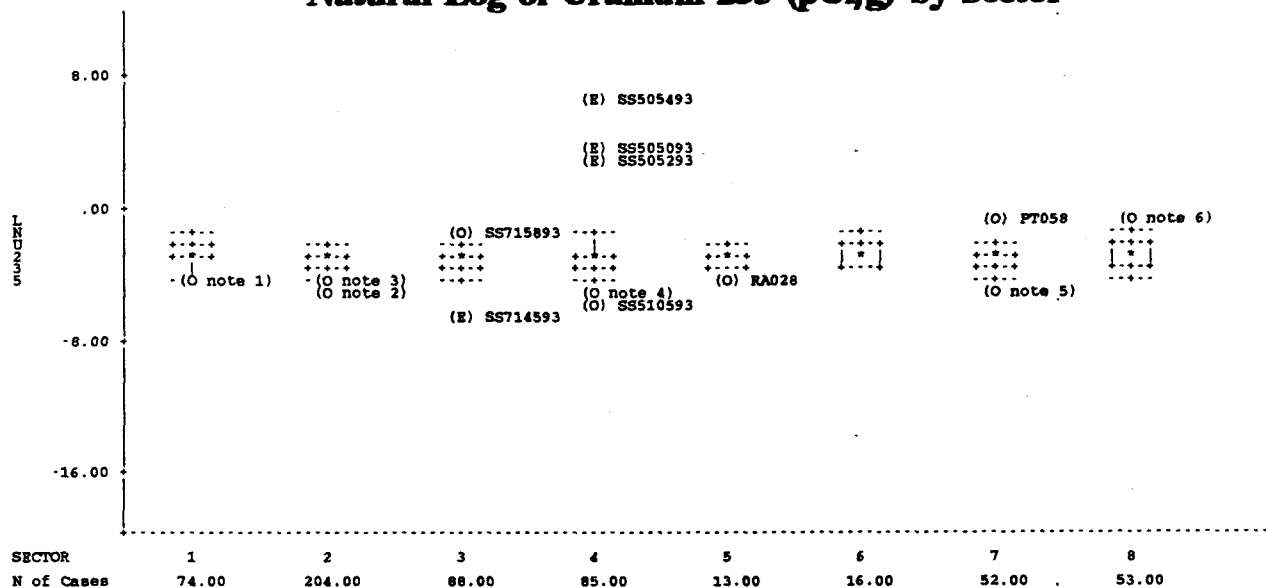
Selenium (mg/kg) by Sector



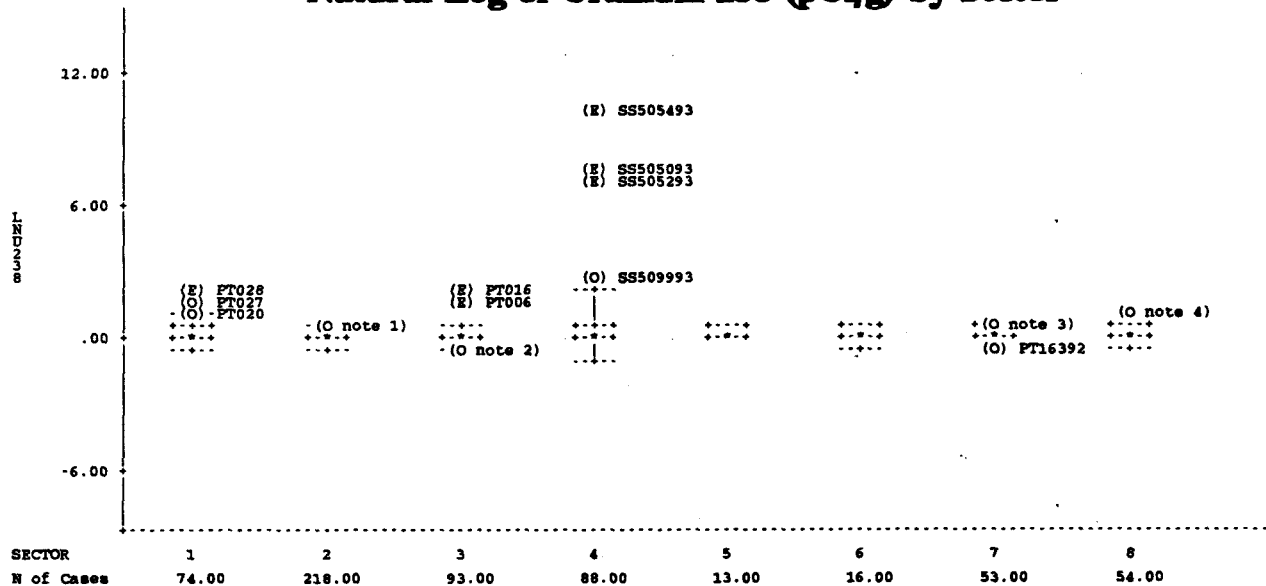
Natural Log of Uranium-233,234 (pCi/g) by Sector



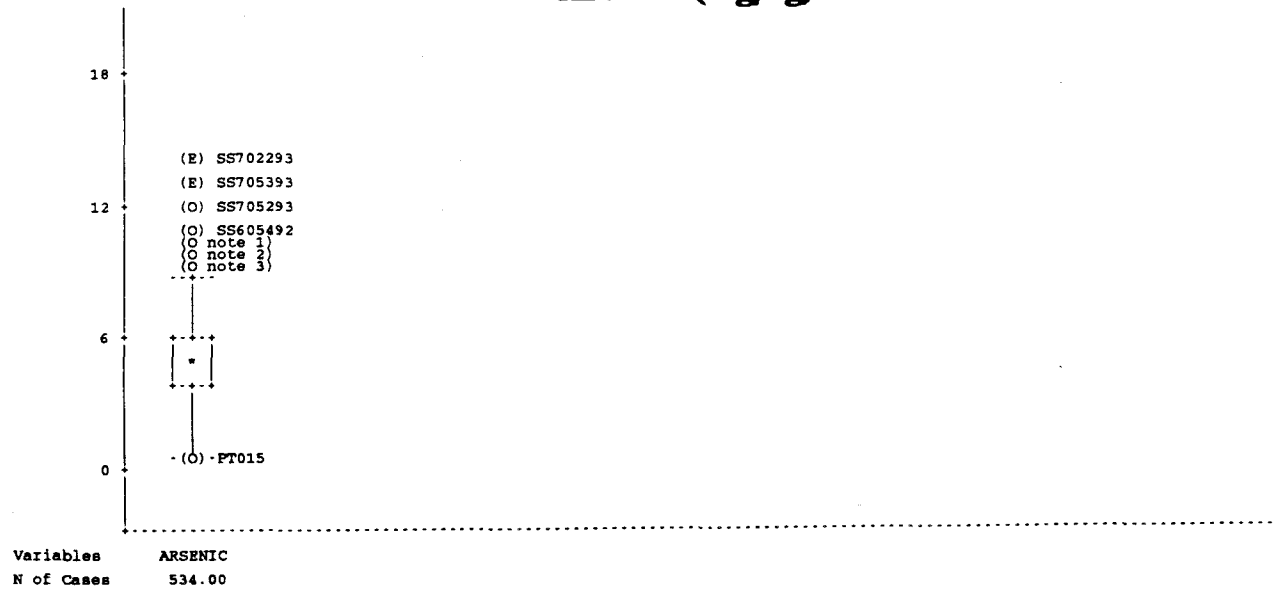
Natural Log of Uranium-235 (pCi/g) by Sector



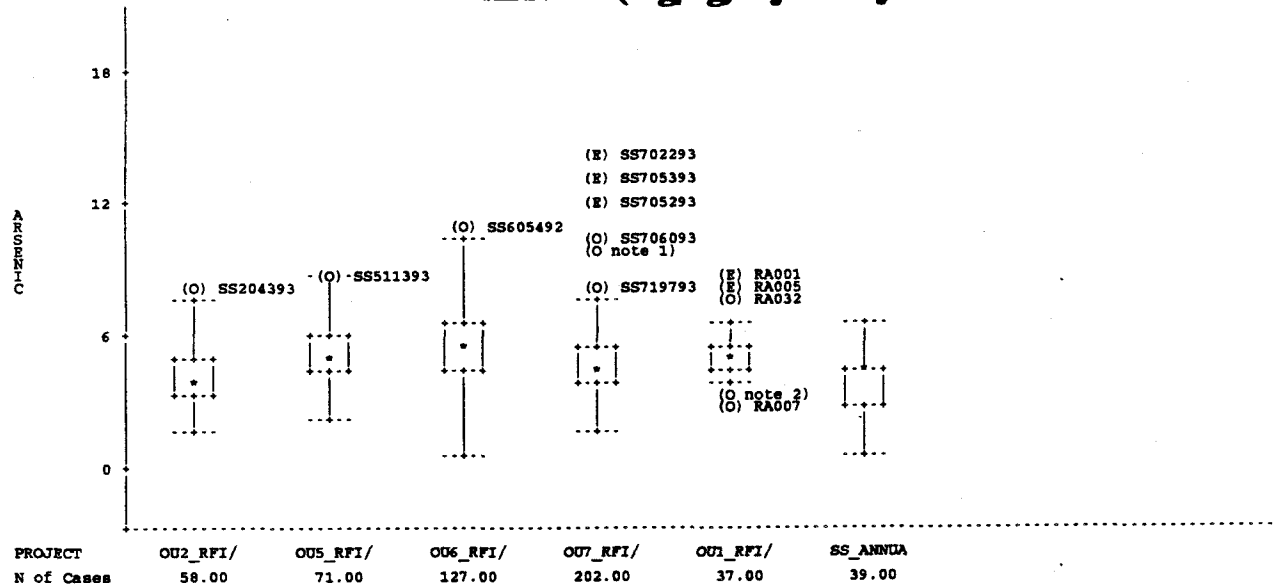
Natural Log of Uranium-238 (pCi/g) by Sector



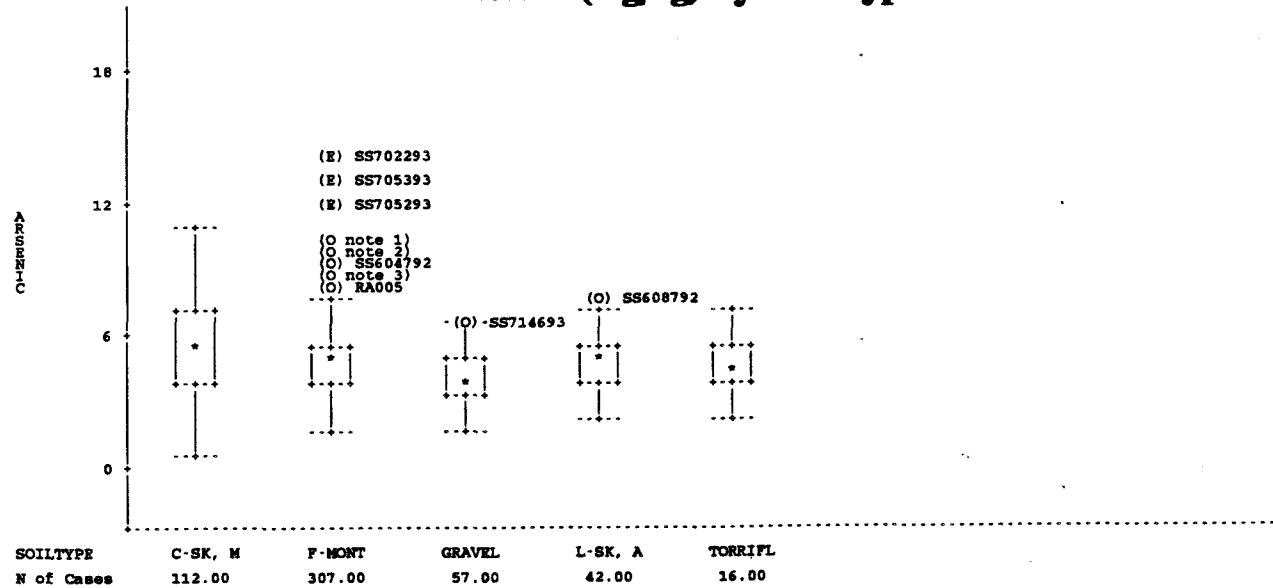
Arsenic (mg/kg)



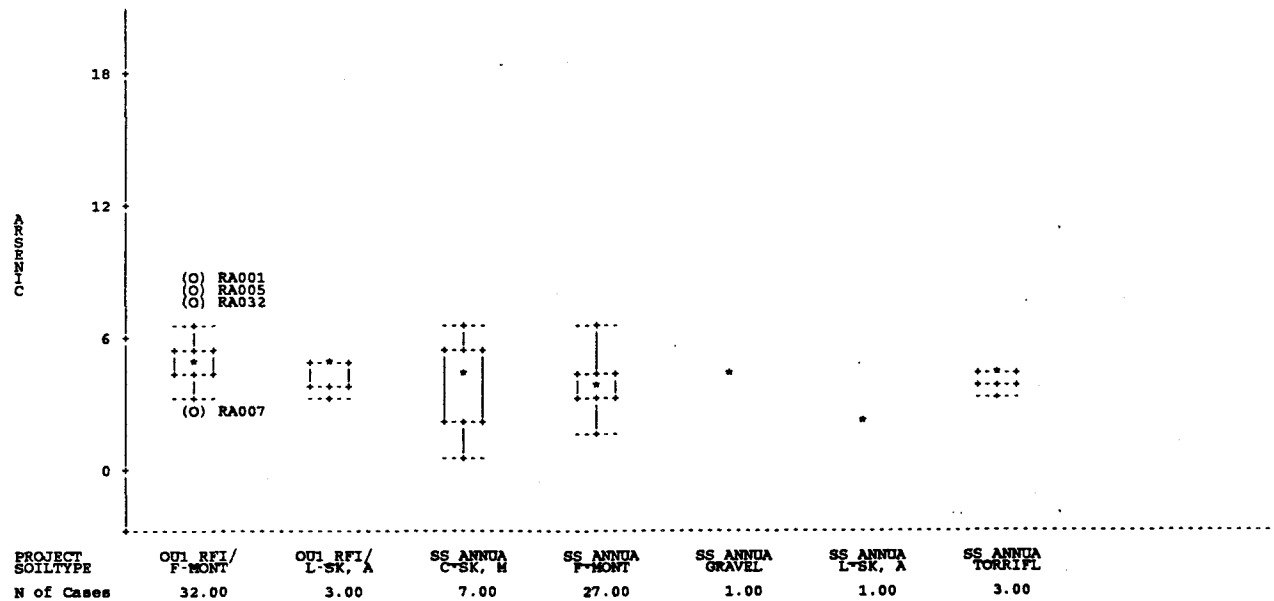
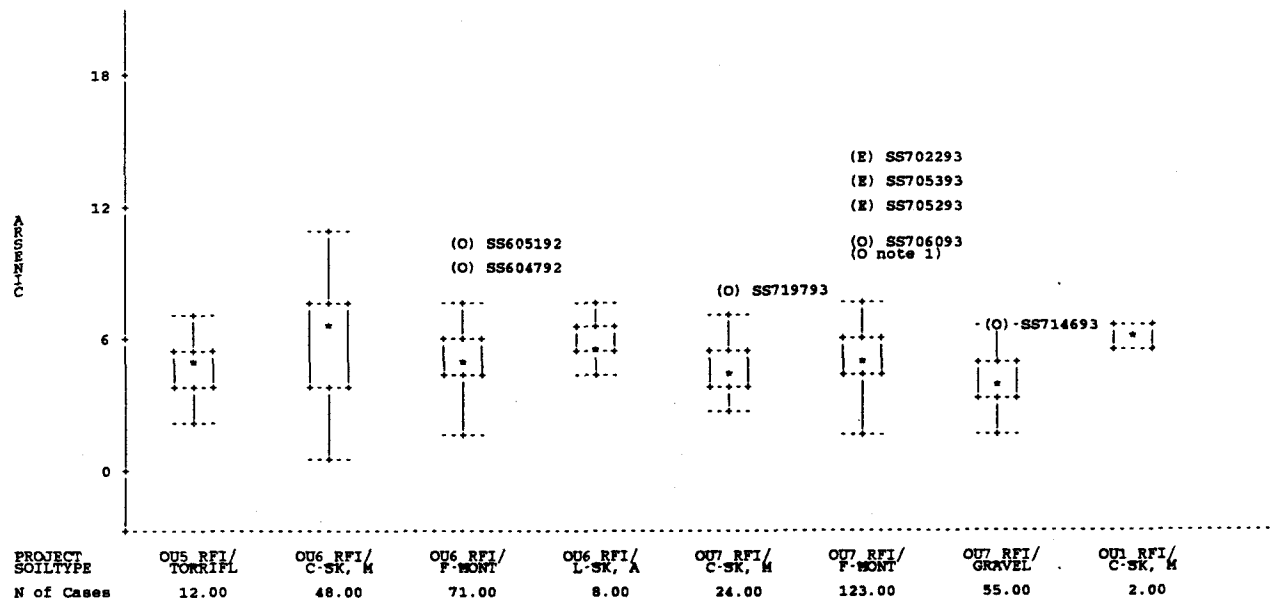
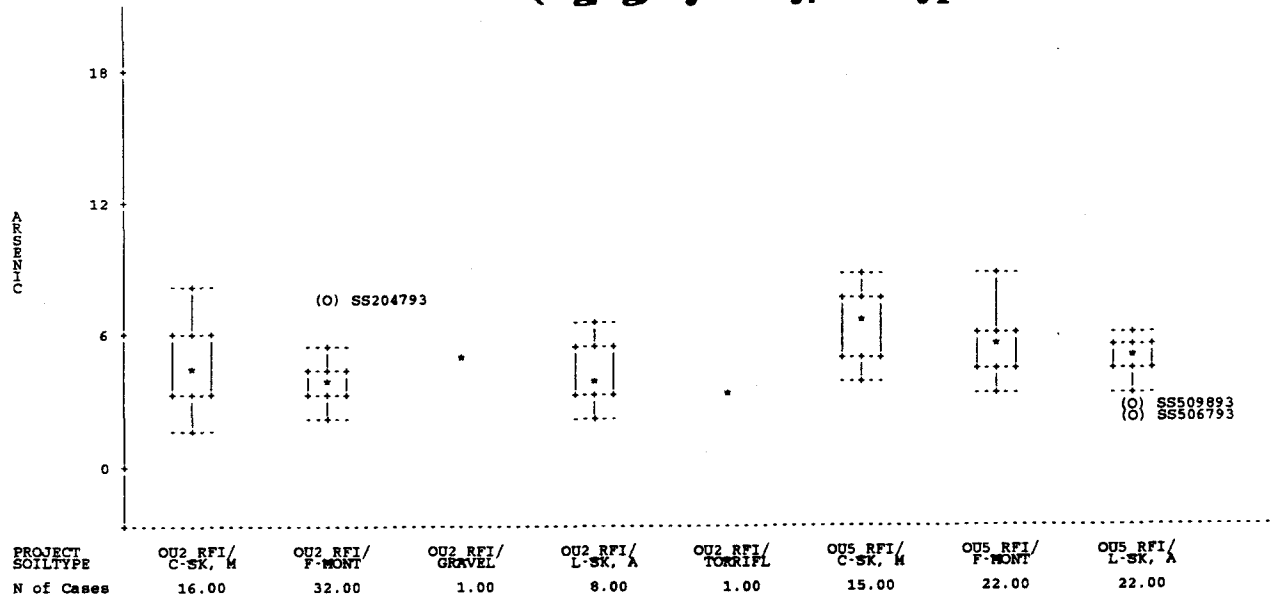
Arsenic (mg/kg) by Study



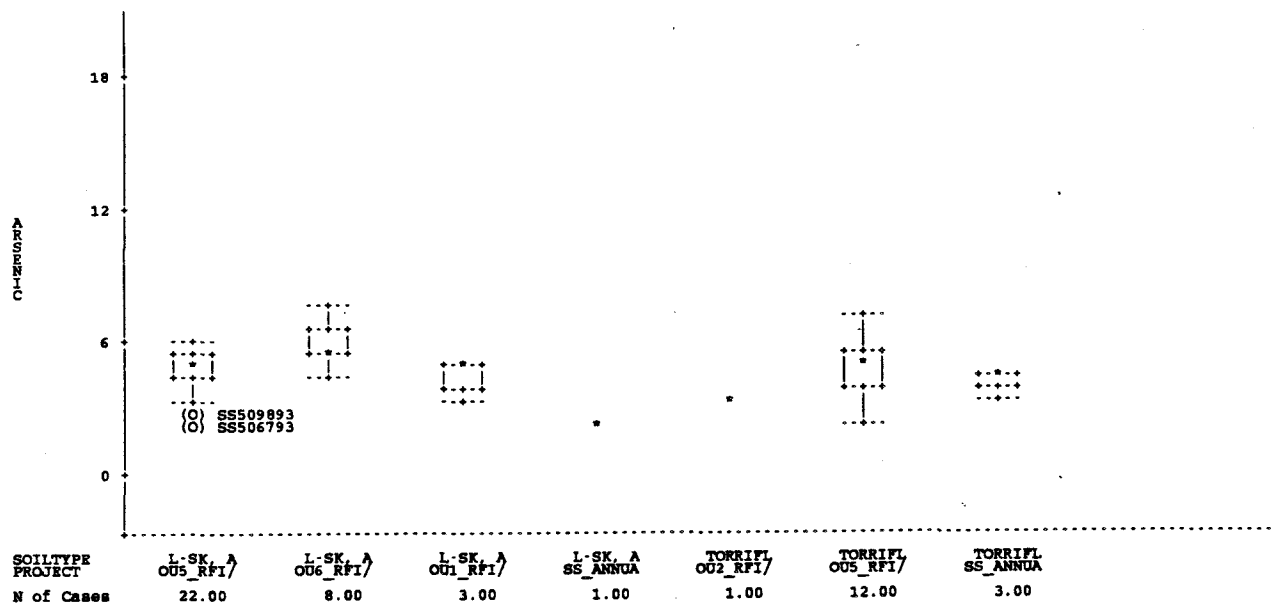
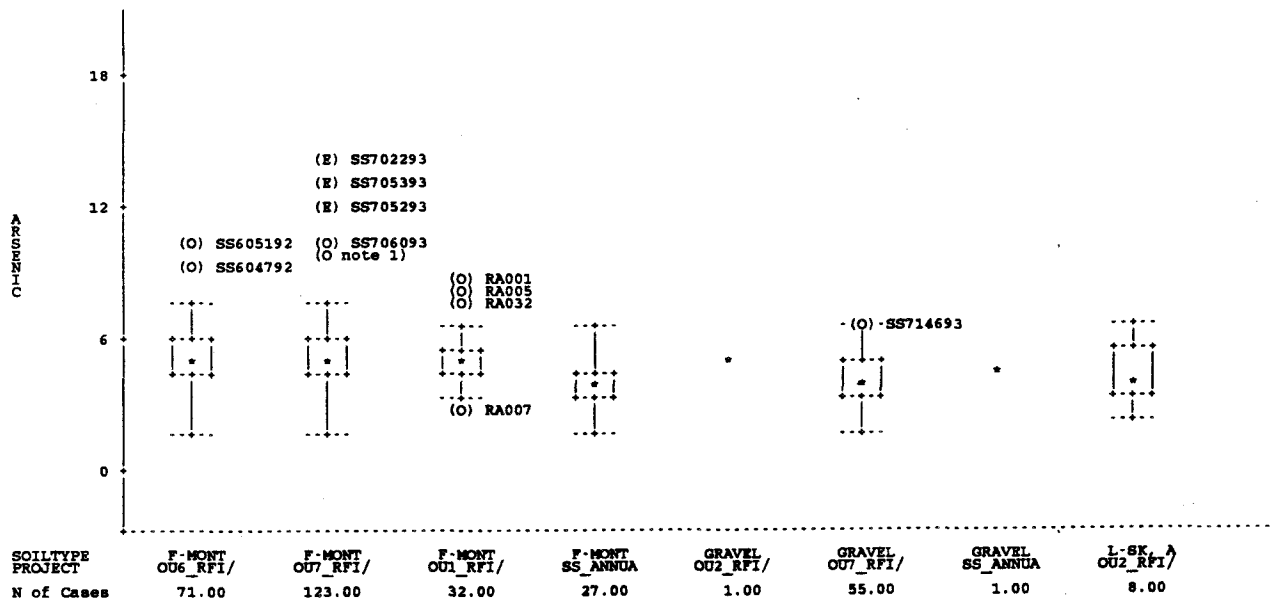
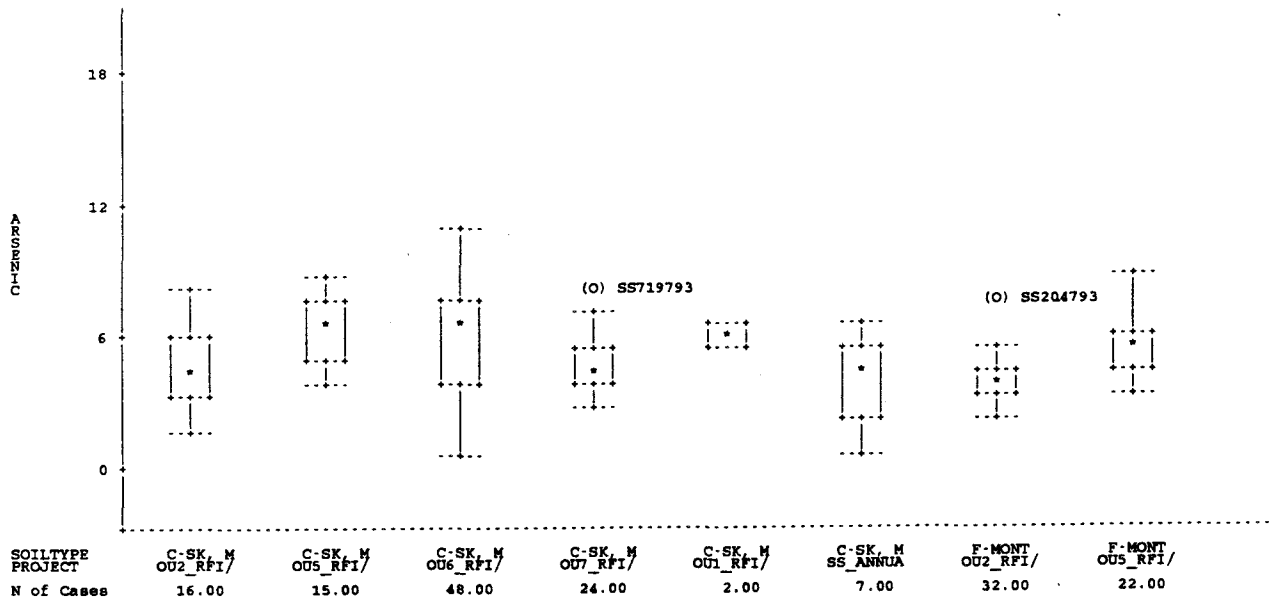
Arsenic (mg/kg) by Soil Types



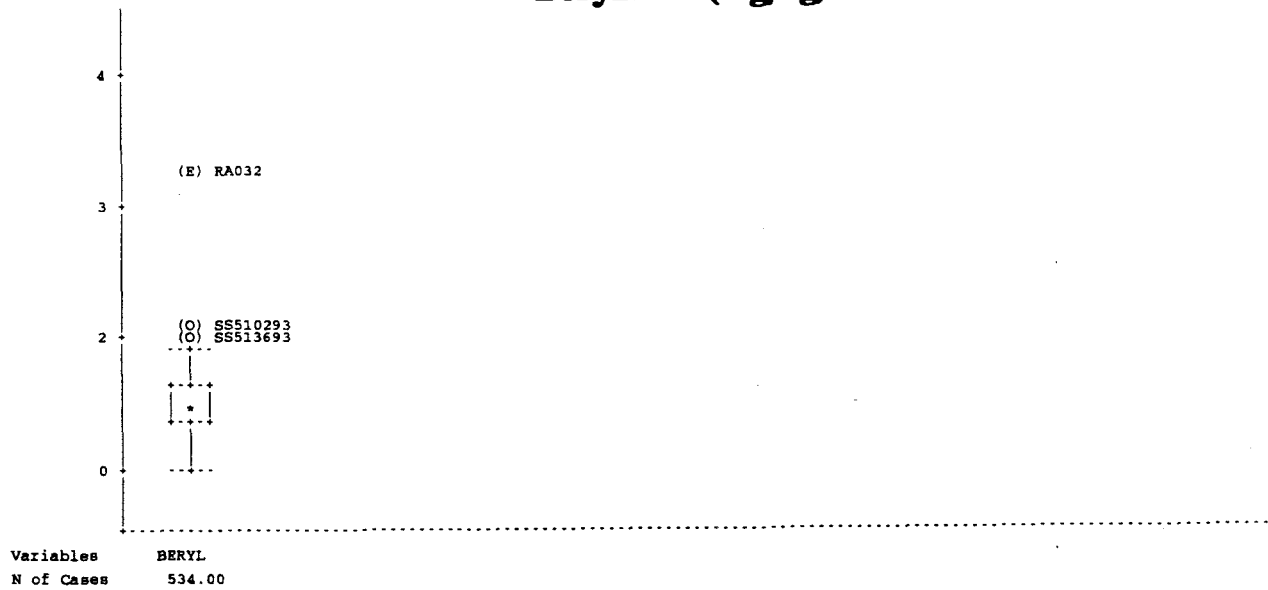
Arsenic (mg/kg) by Study/Soil Type



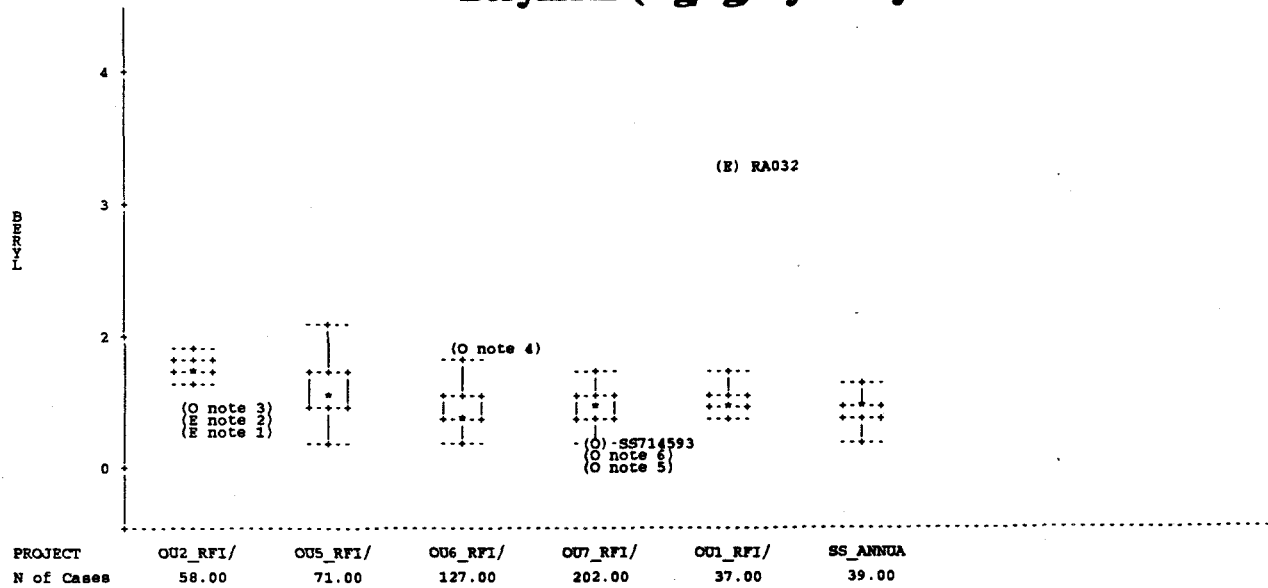
Arsenic (mg/kg) by Soil Type/Study



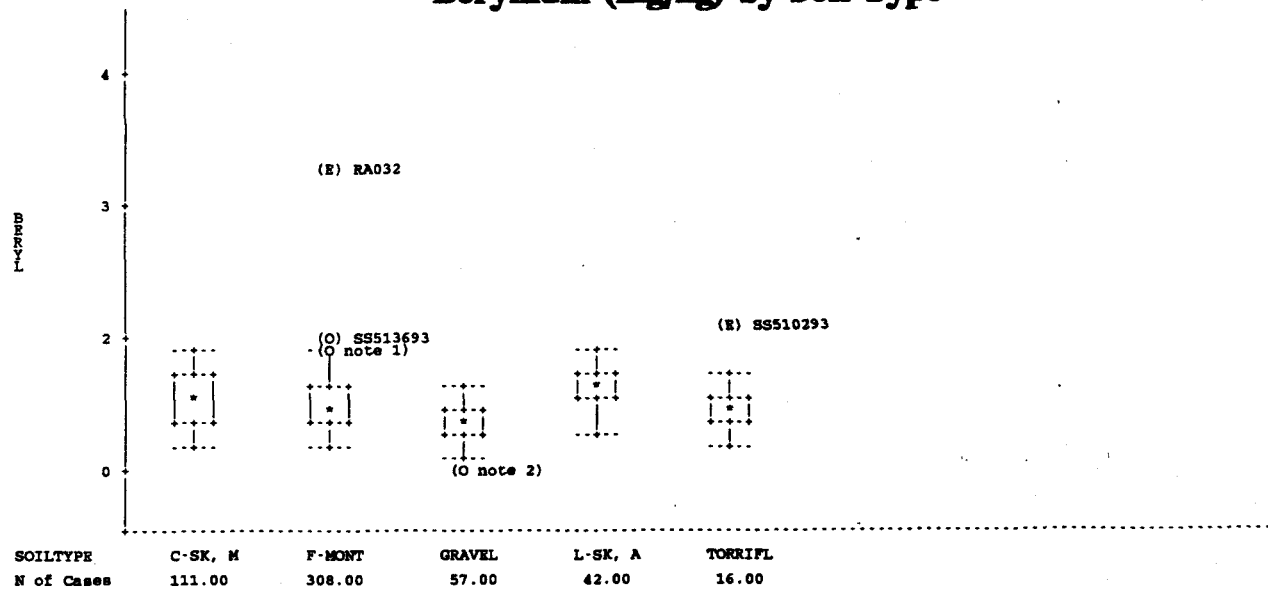
Beryllium (mg/kg)



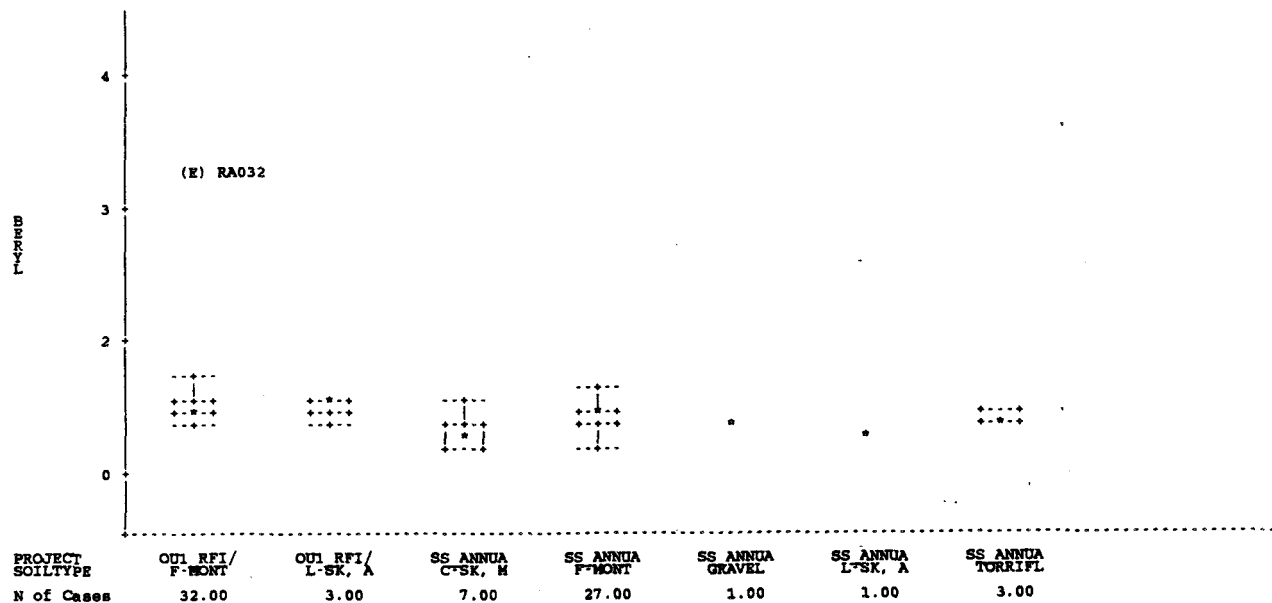
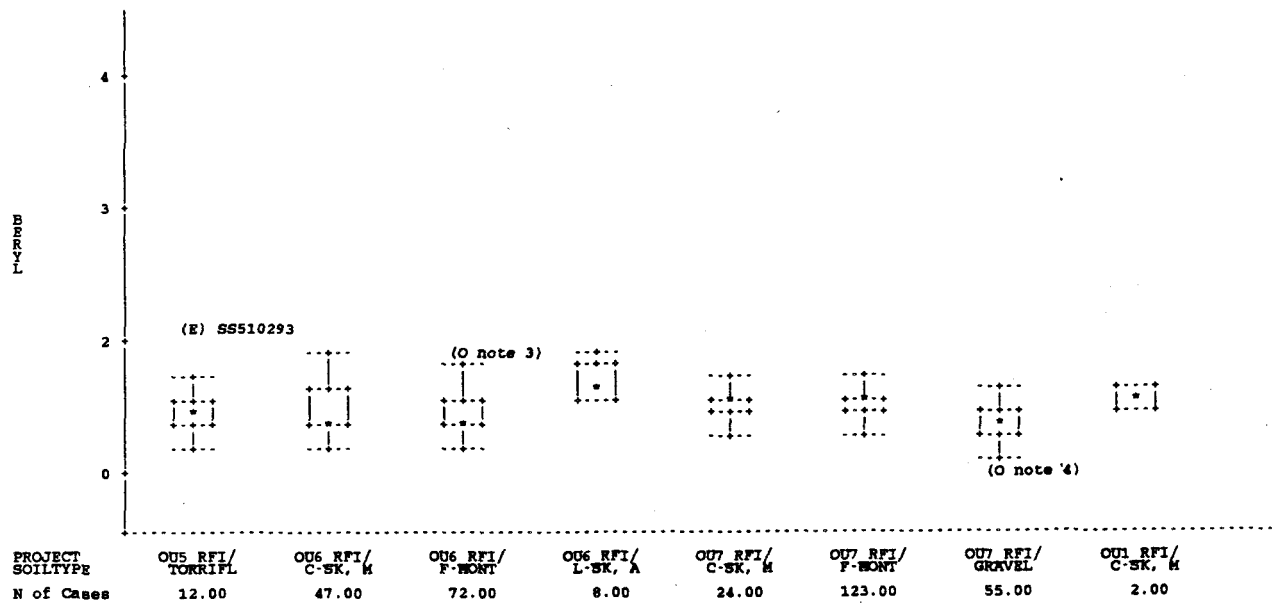
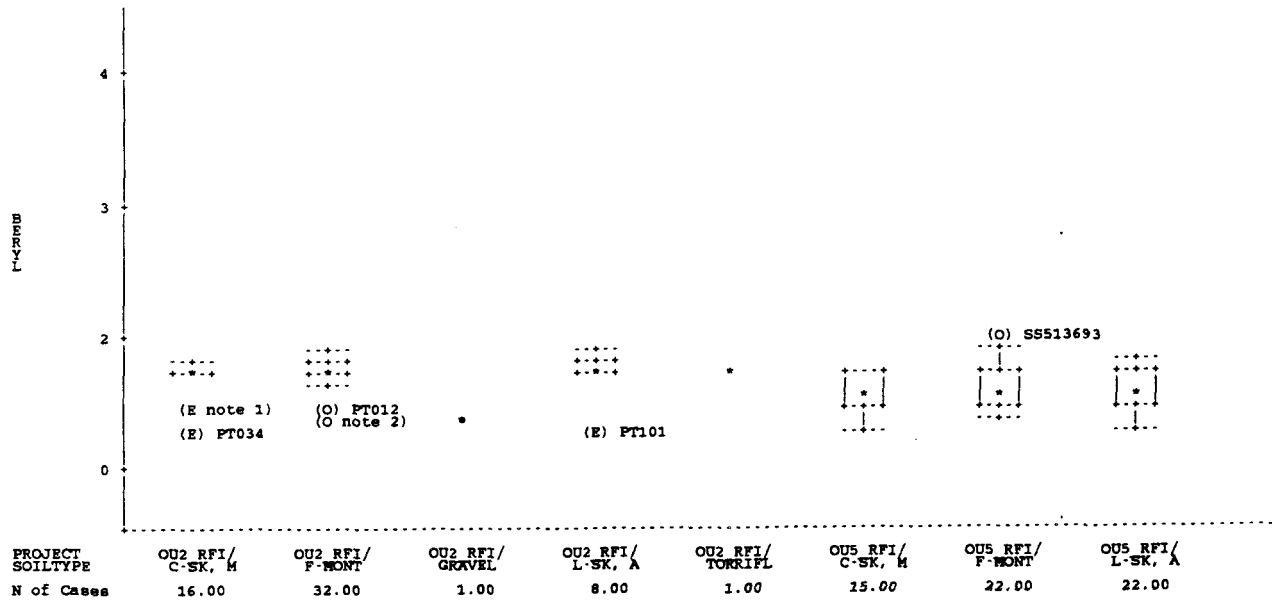
Beryllium (mg/kg) by Study



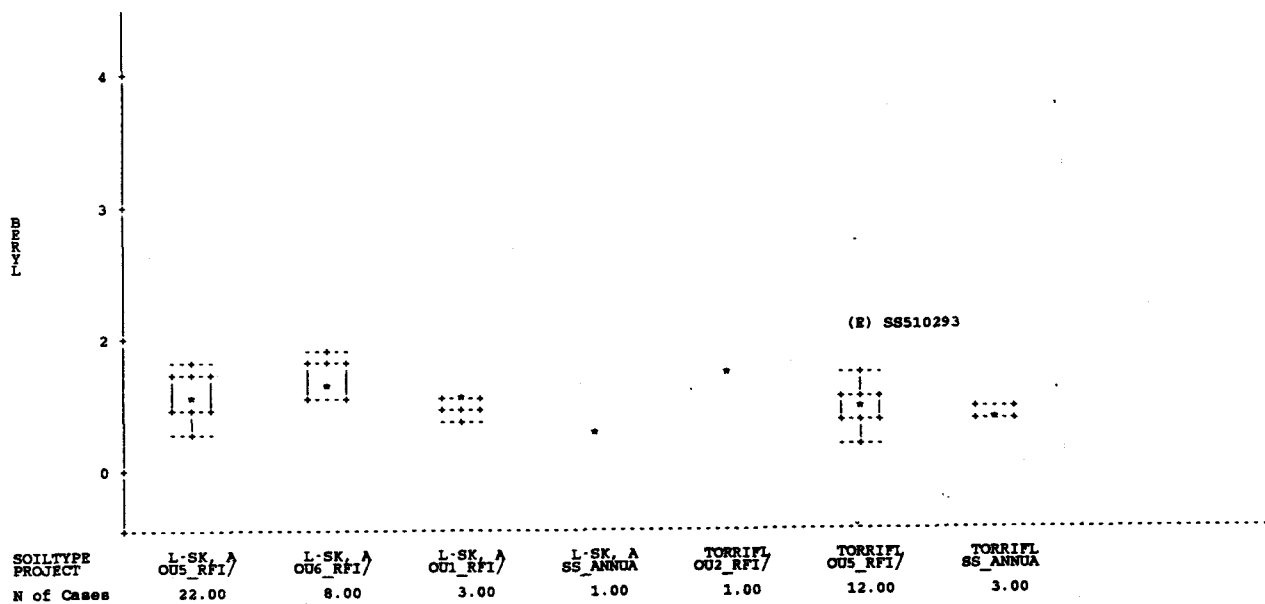
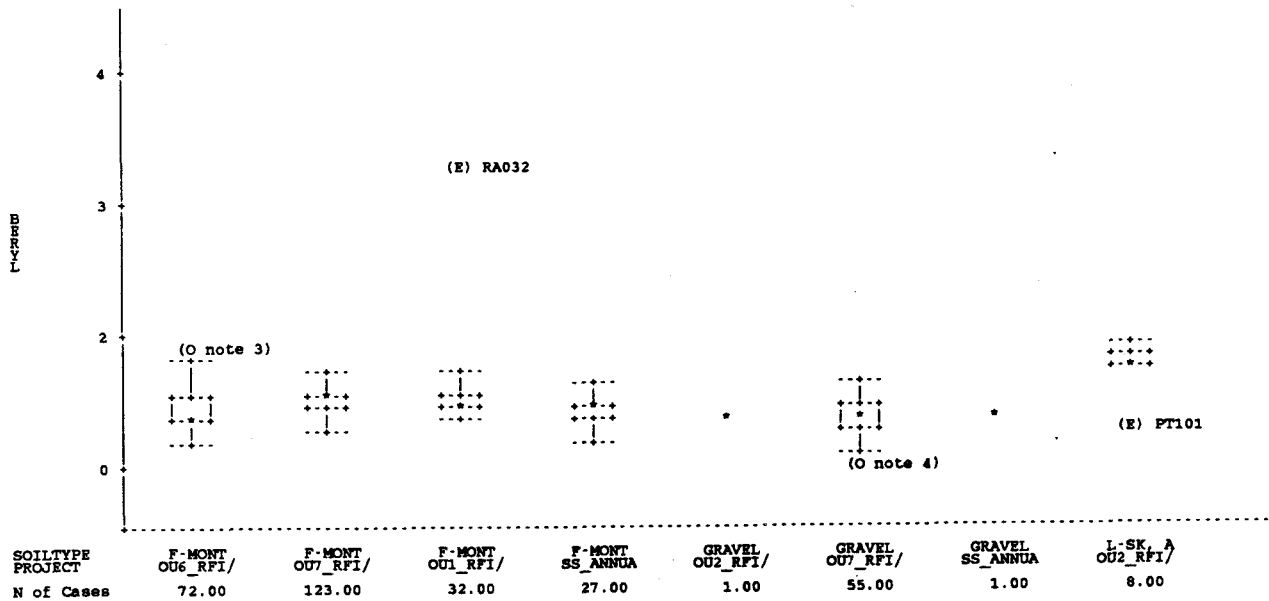
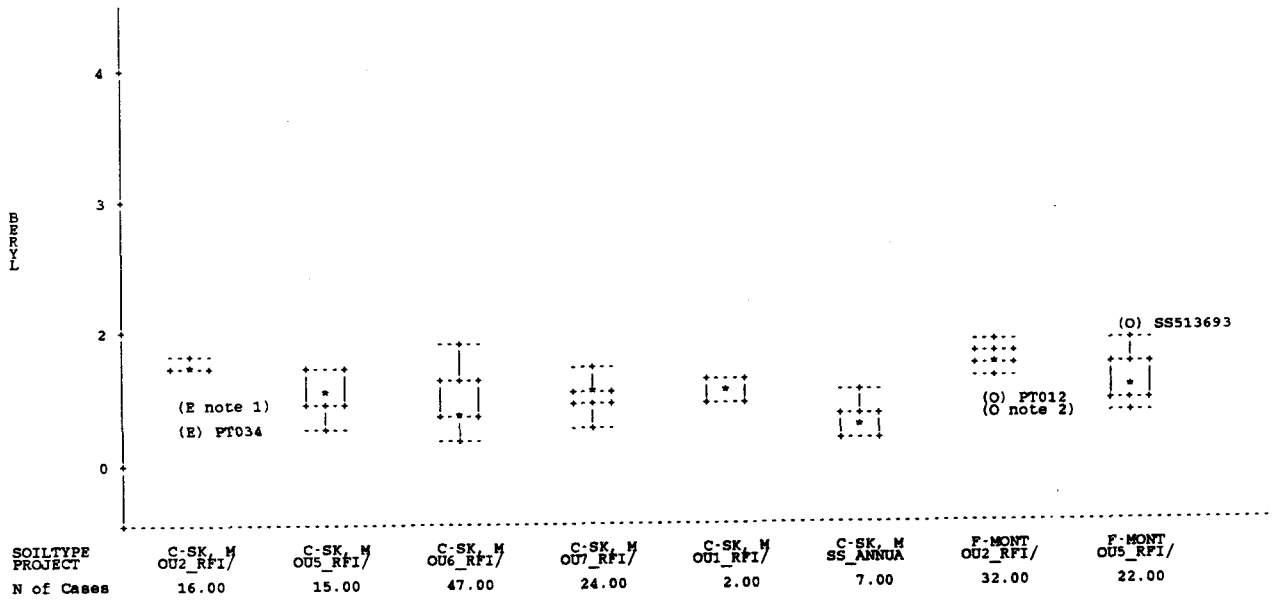
Beryllium (mg/kg) by Soil Type



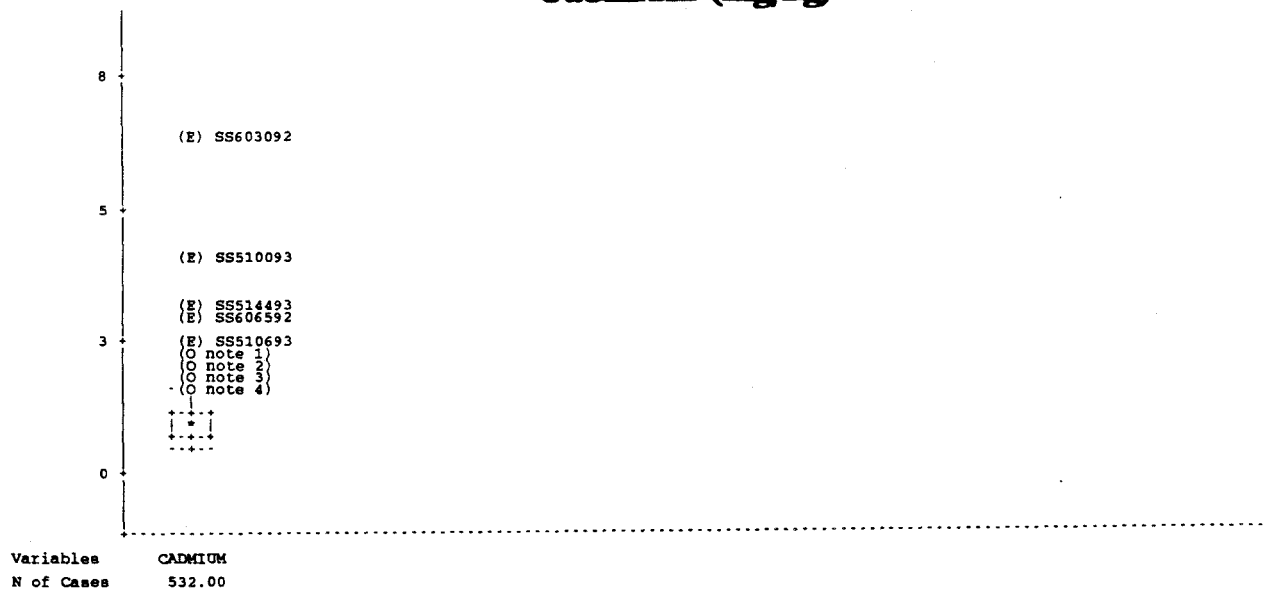
Beryllium (mg/kg) by Study/Soil Type



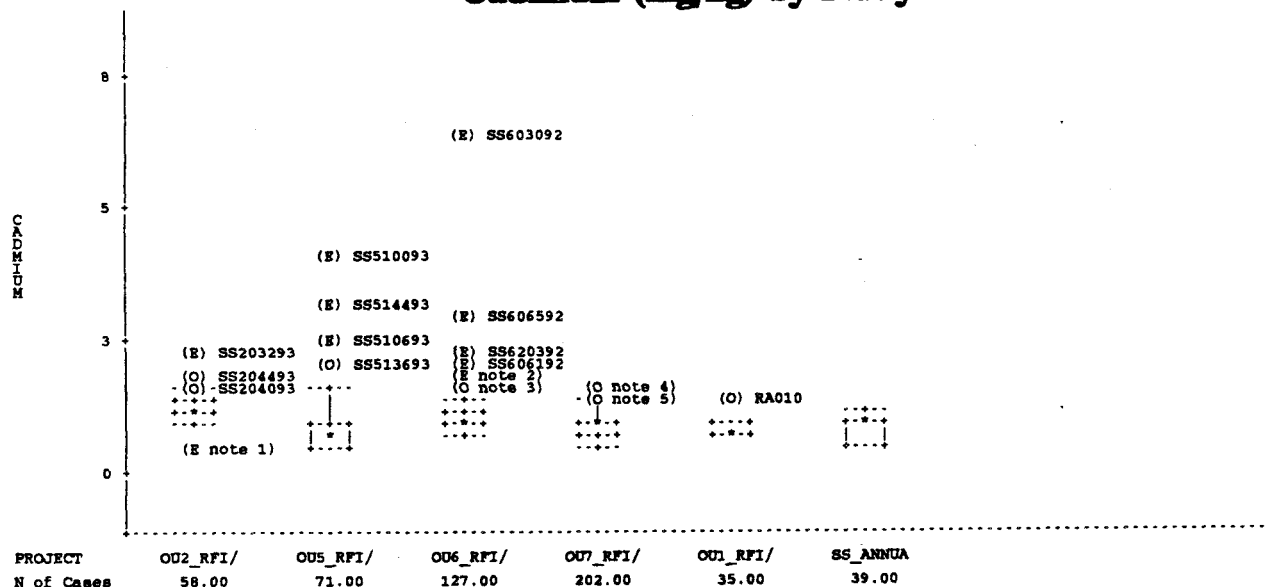
Beryllium (mg/kg) by Soil Type/Study



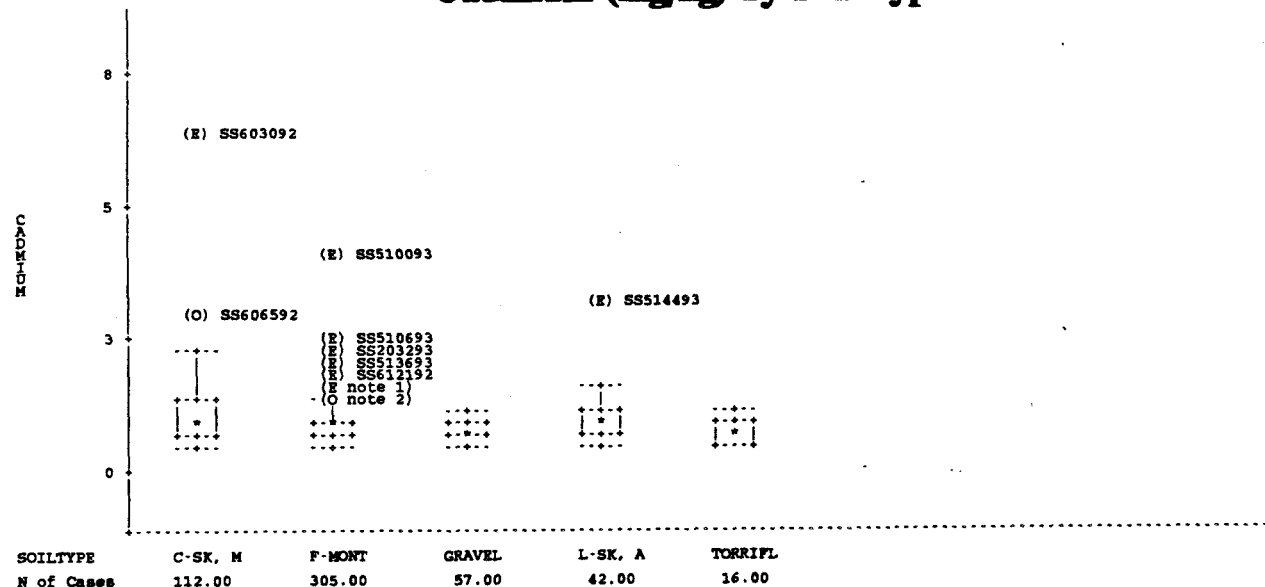
Cadmium (mg/kg)



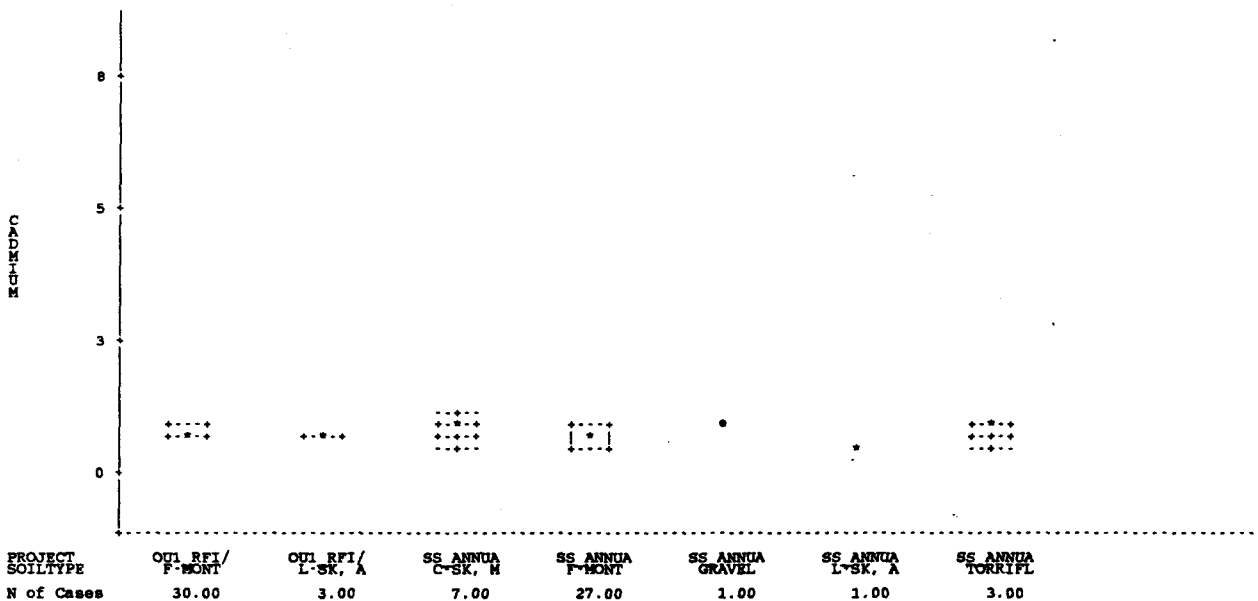
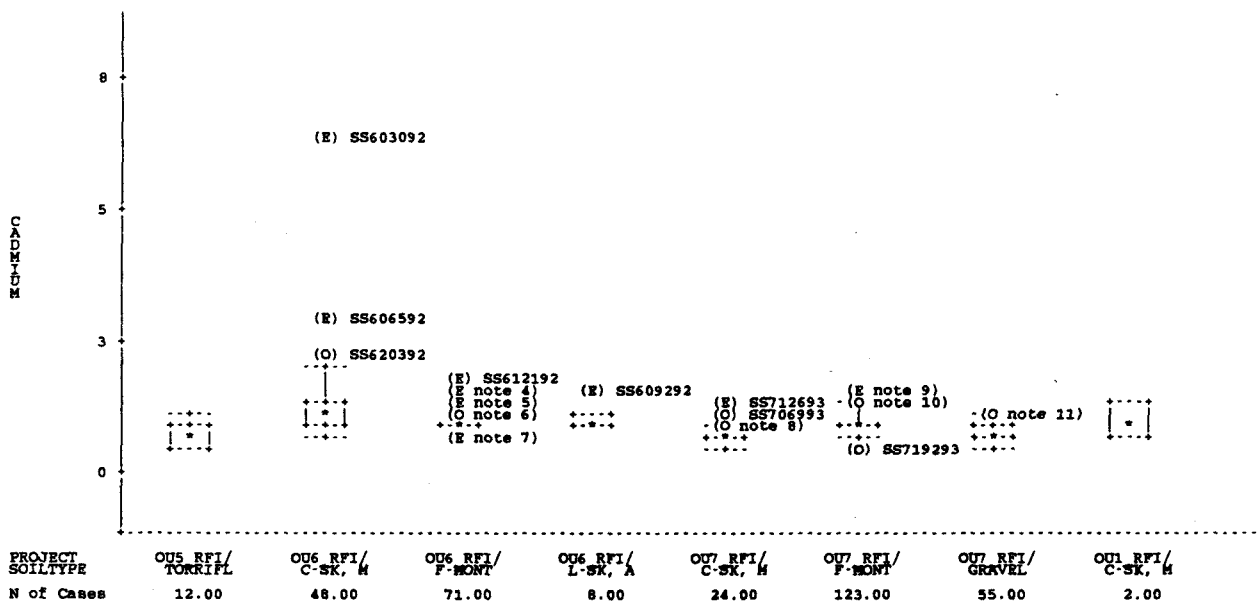
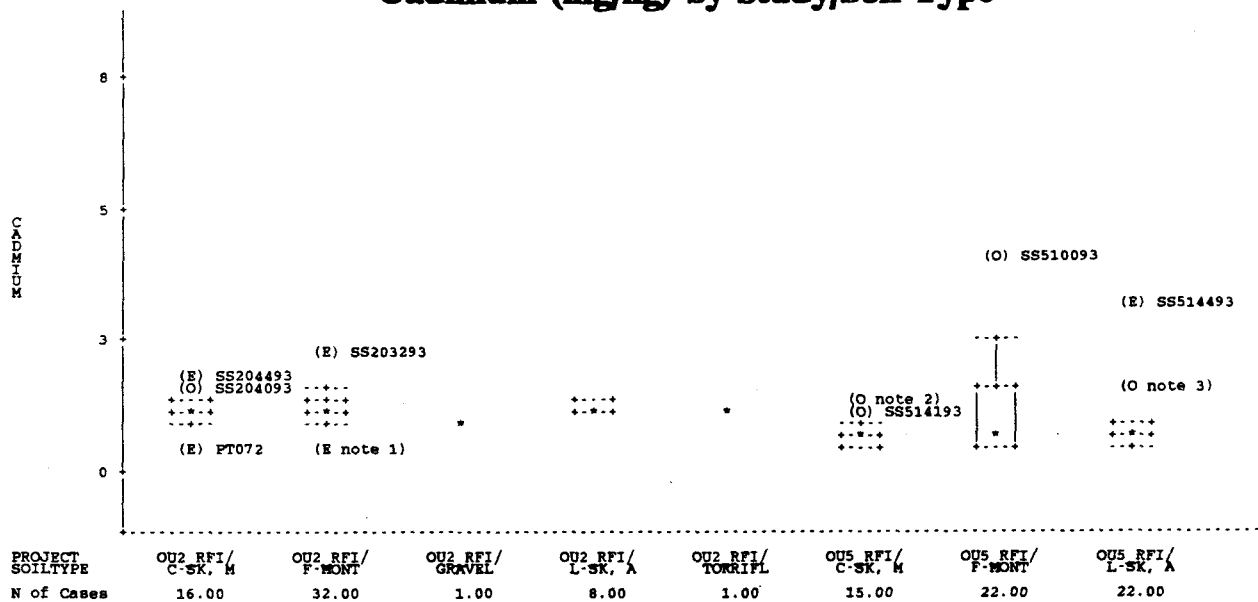
Cadmium (mg/kg) by Study



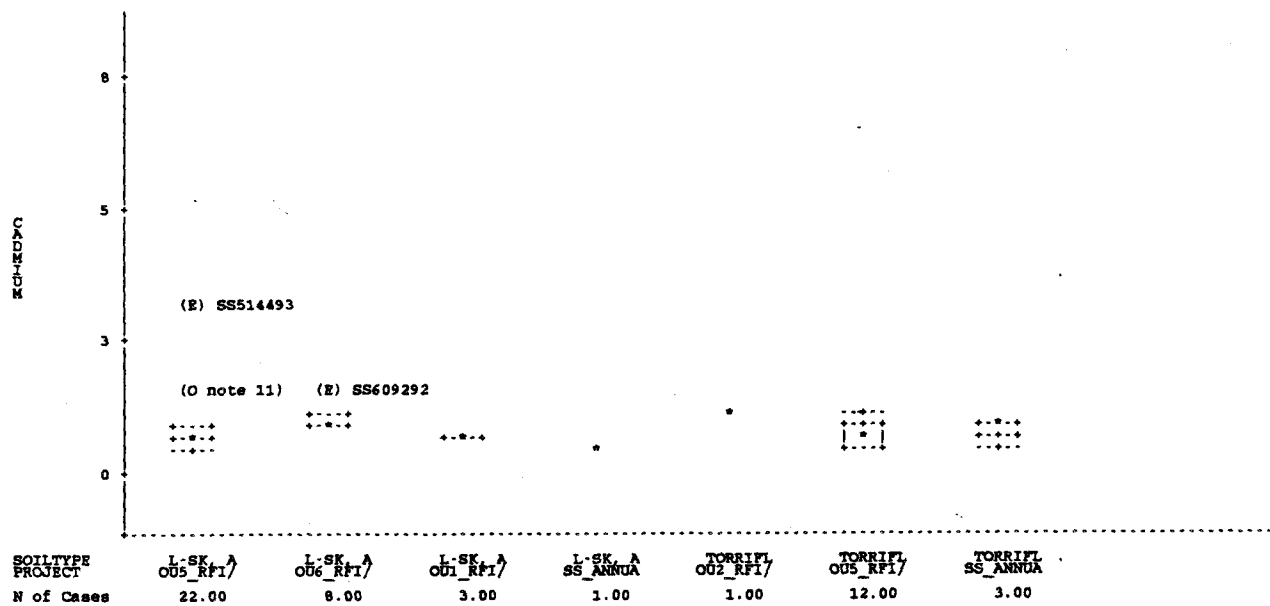
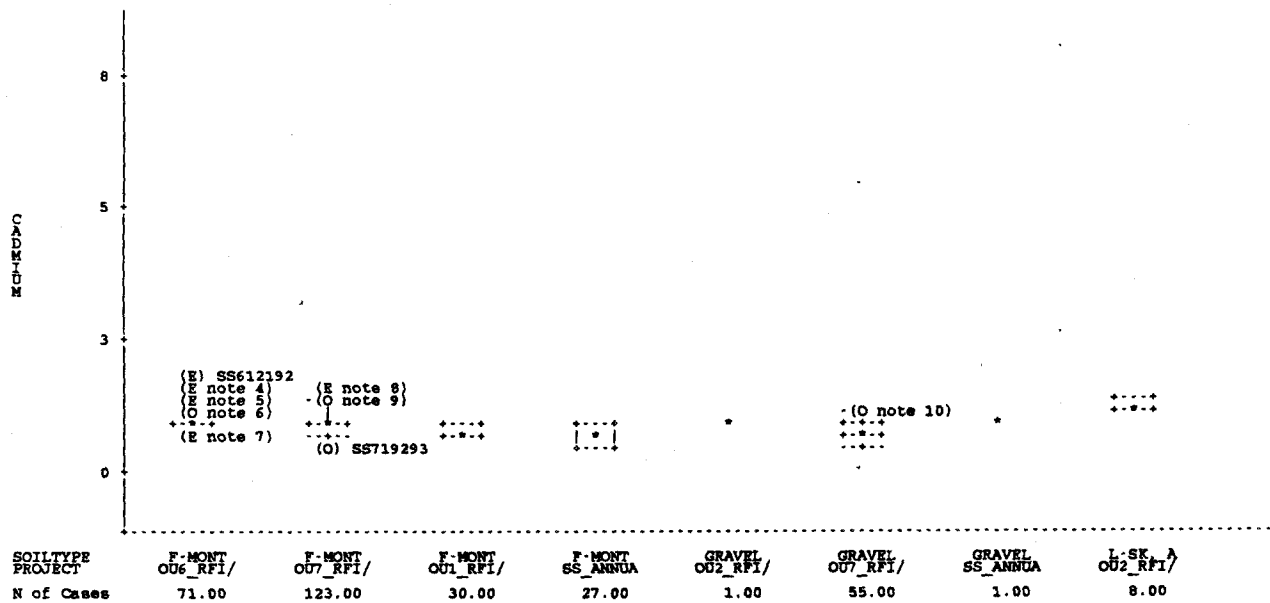
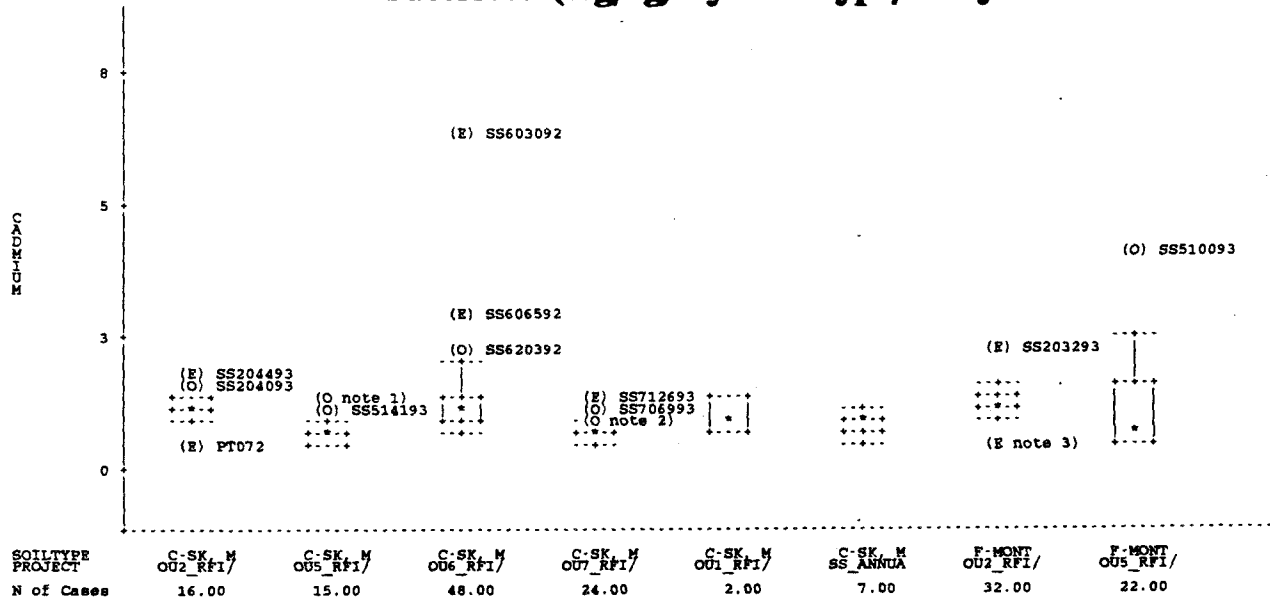
Cadmium (mg/kg) by Soil Type



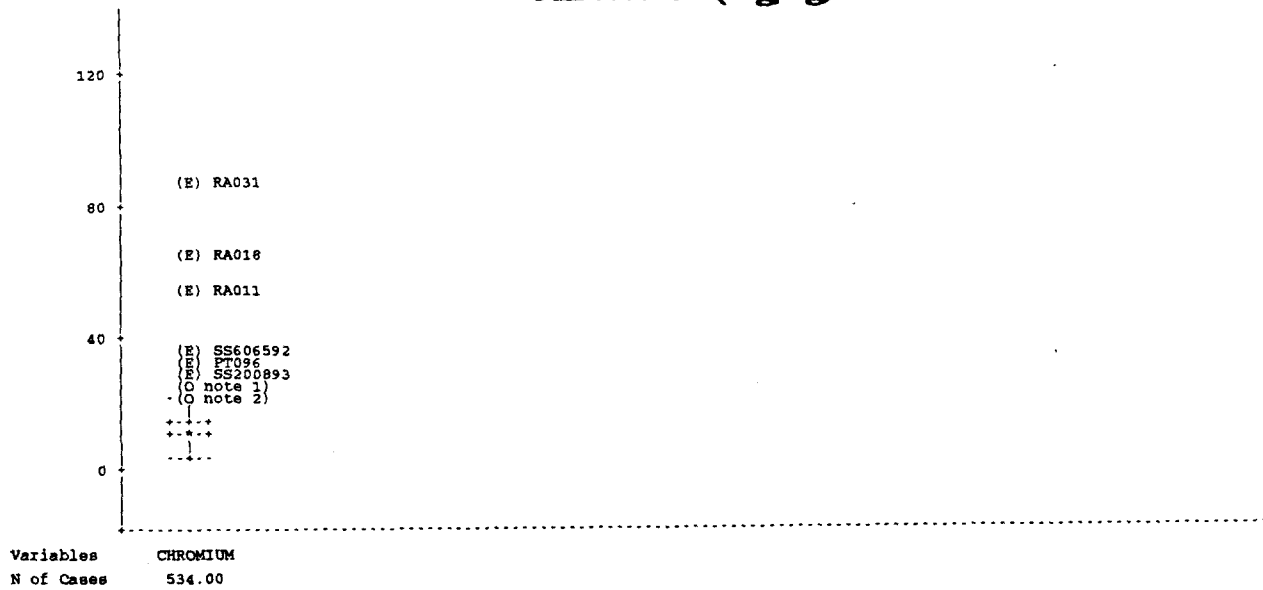
Cadmium (mg/kg) by Study/Soil Type



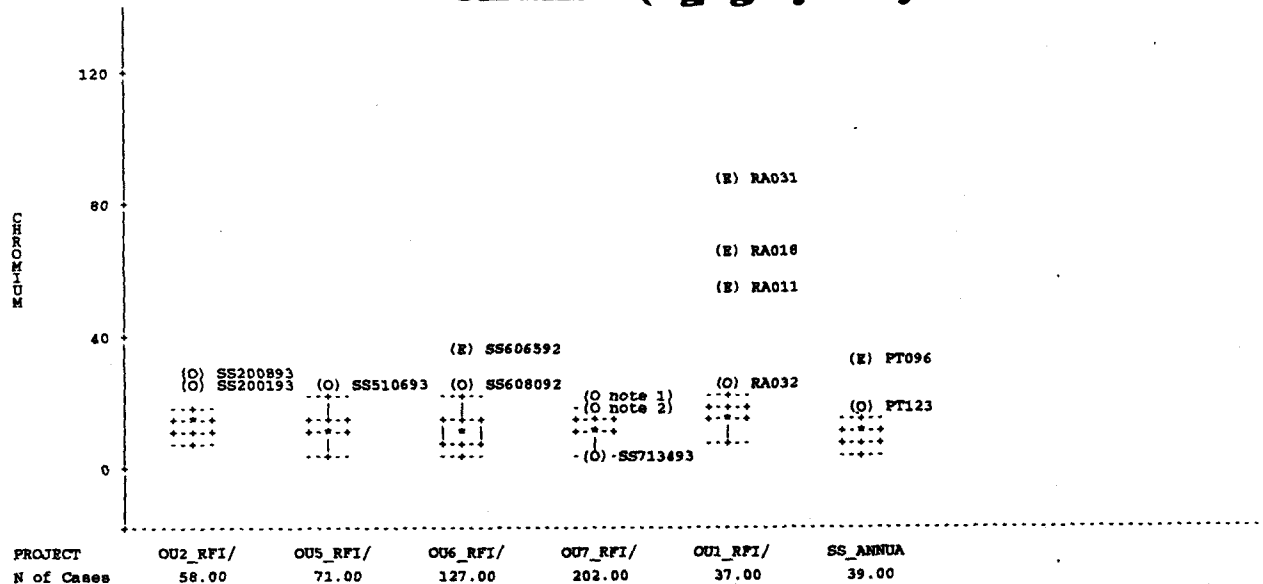
Cadmium (mg/kg) by Soil Type/Study



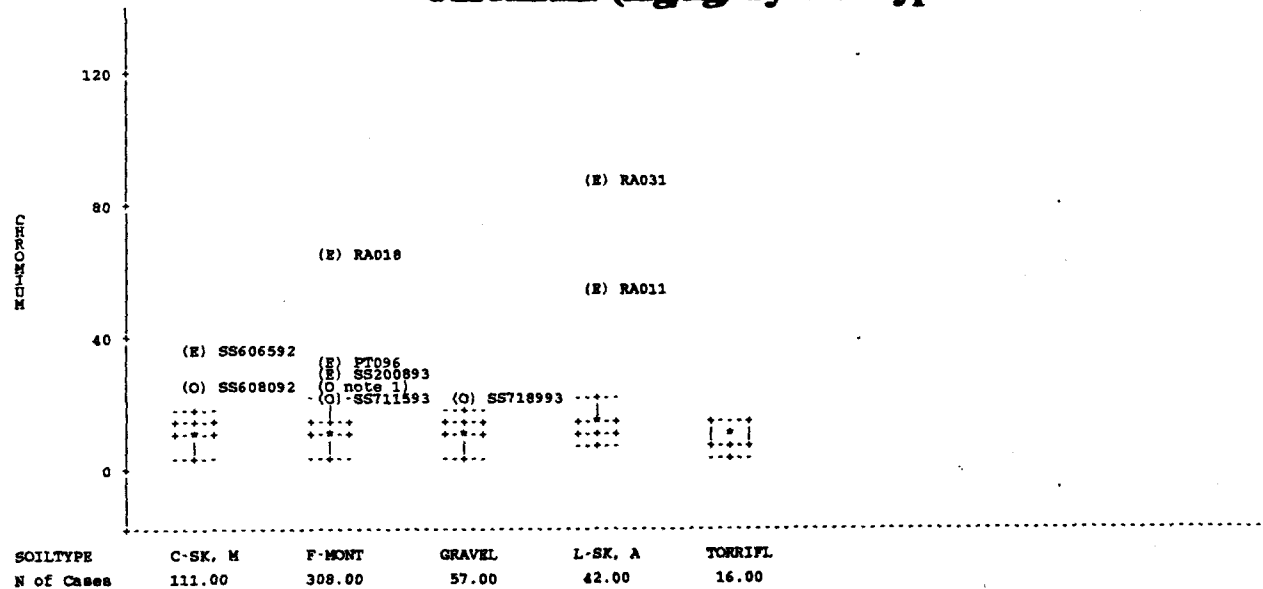
Chromium (mg/kg)



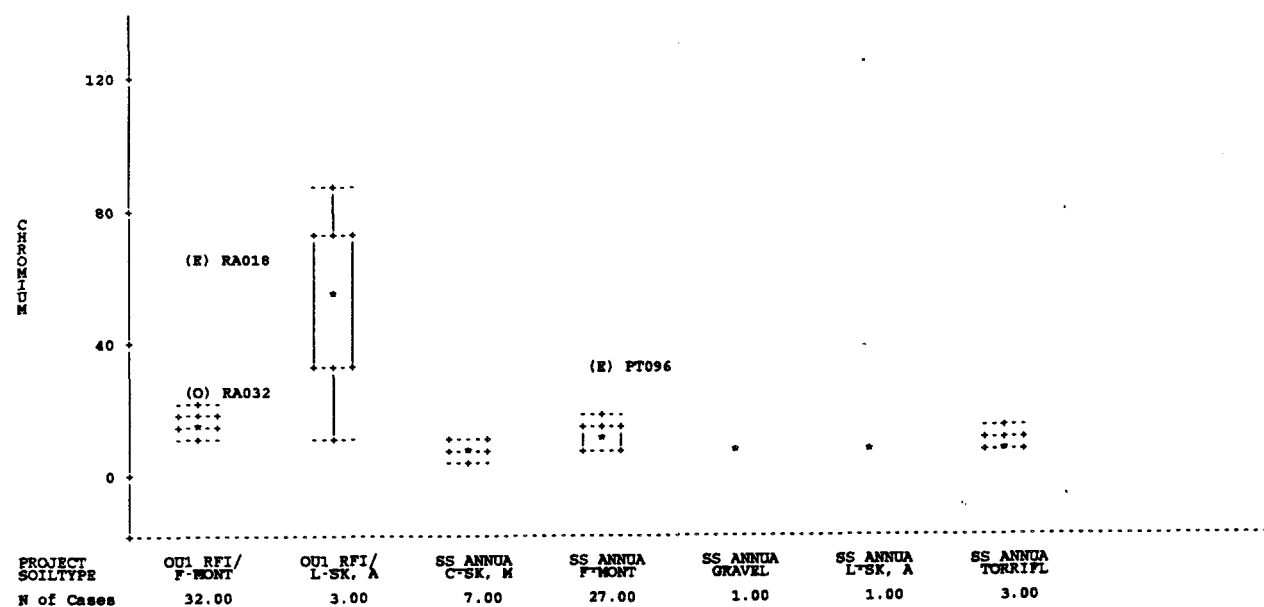
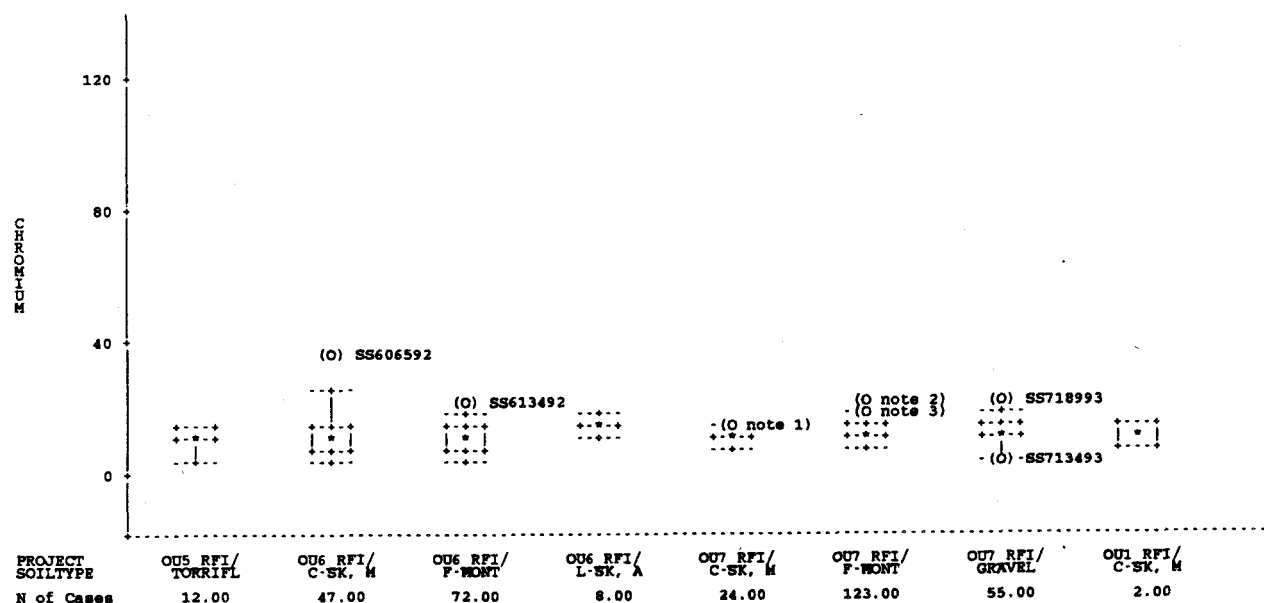
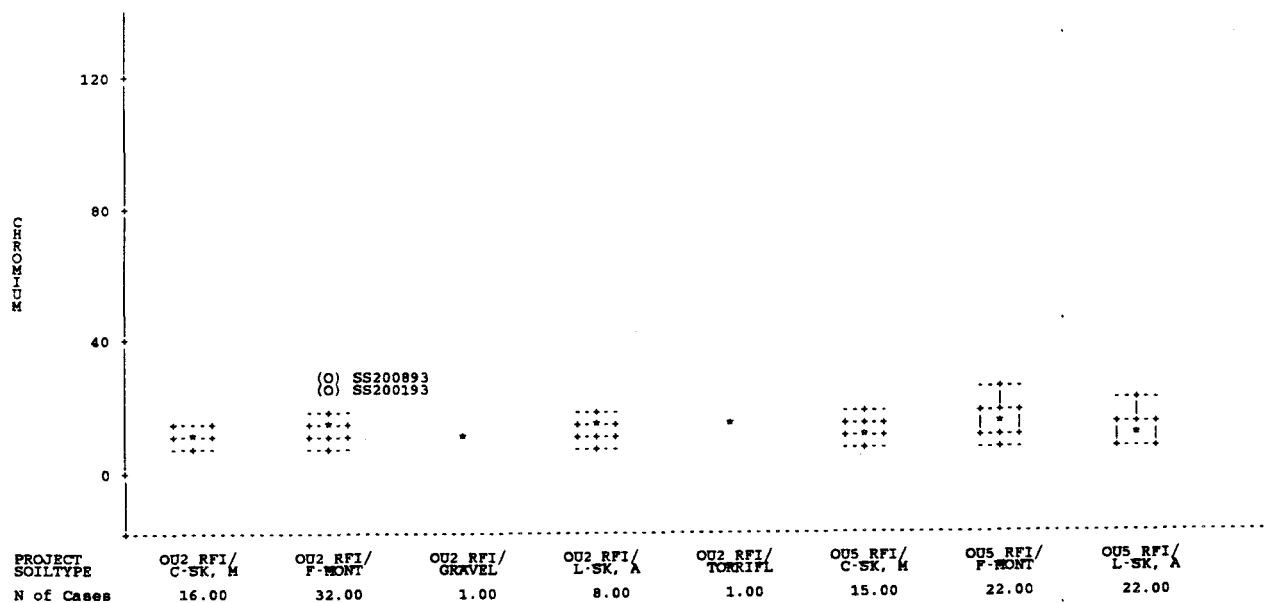
Chromium (mg/kg) by Study



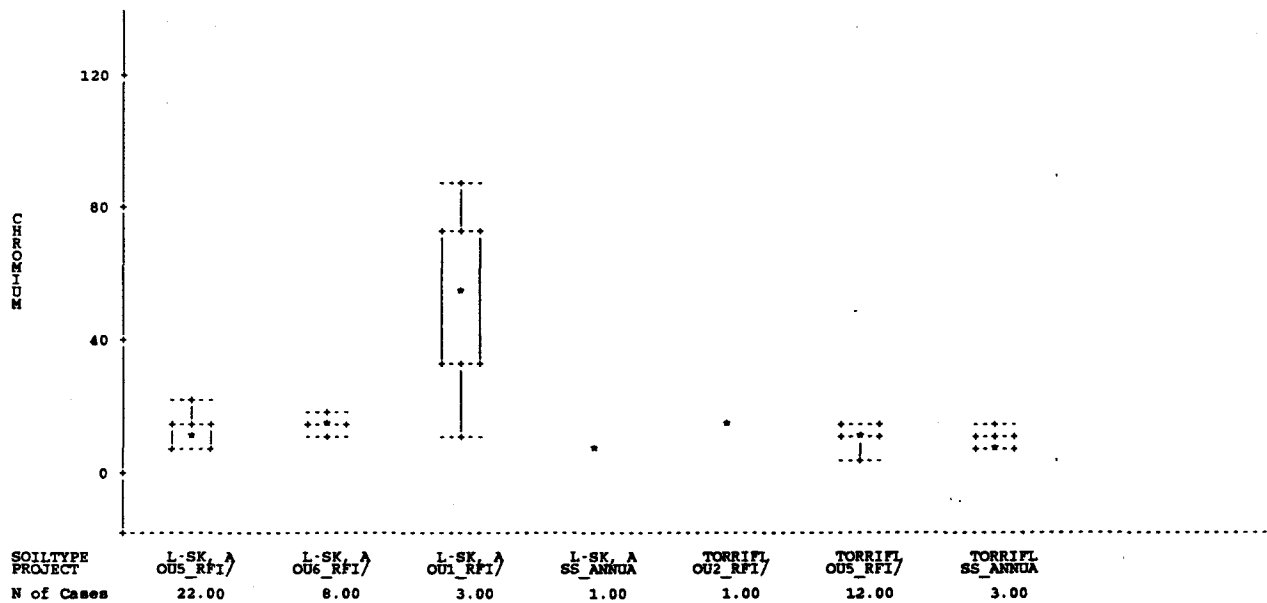
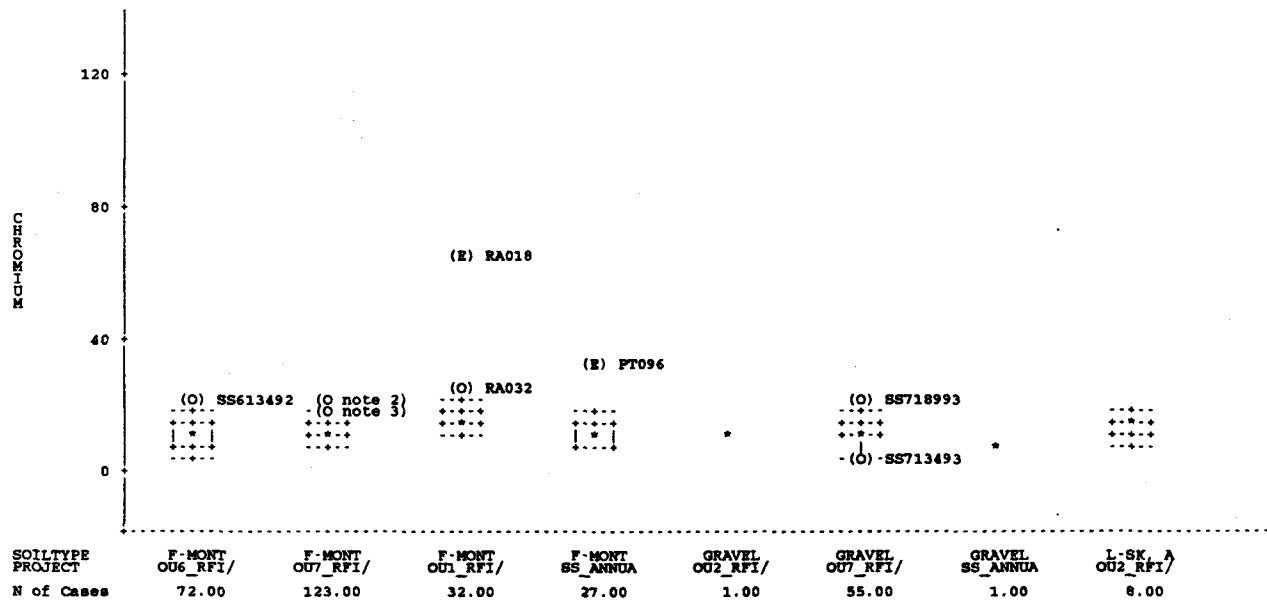
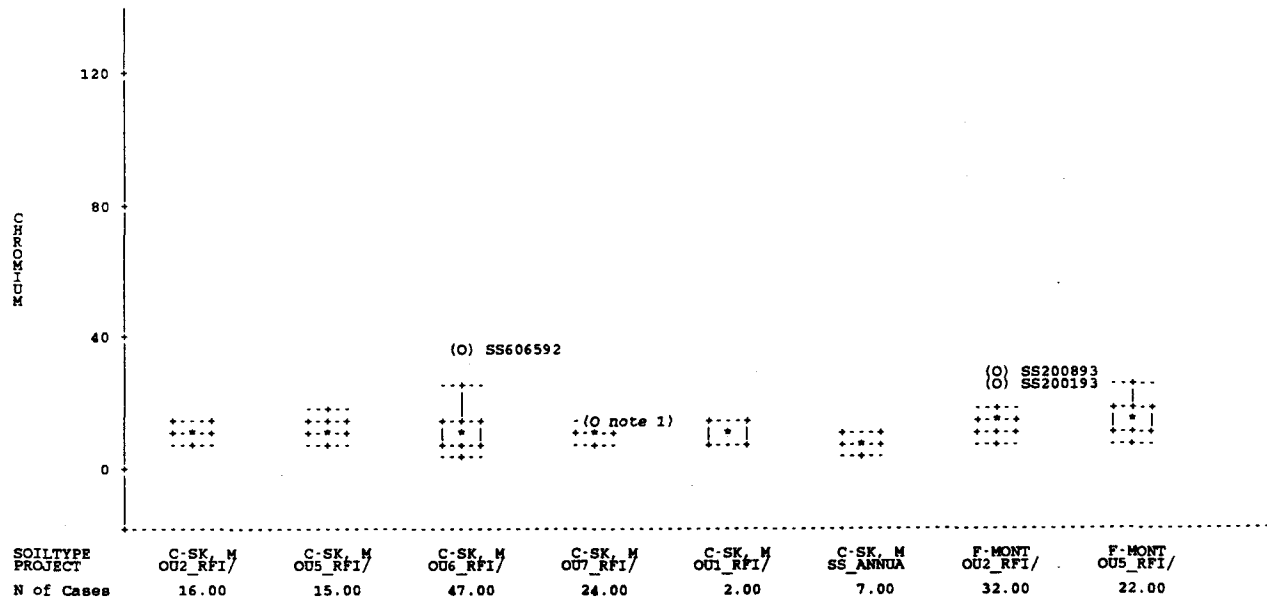
Chromium (mg/kg) by Soil Type



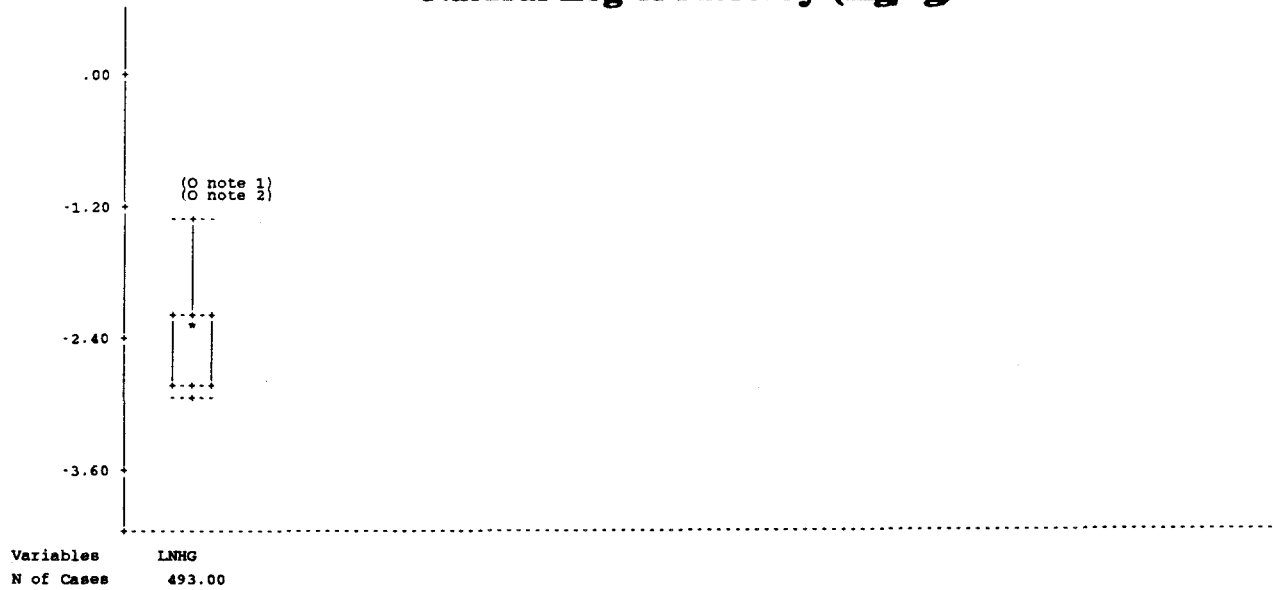
Chromium (mg/kg) by Study/Soil Type



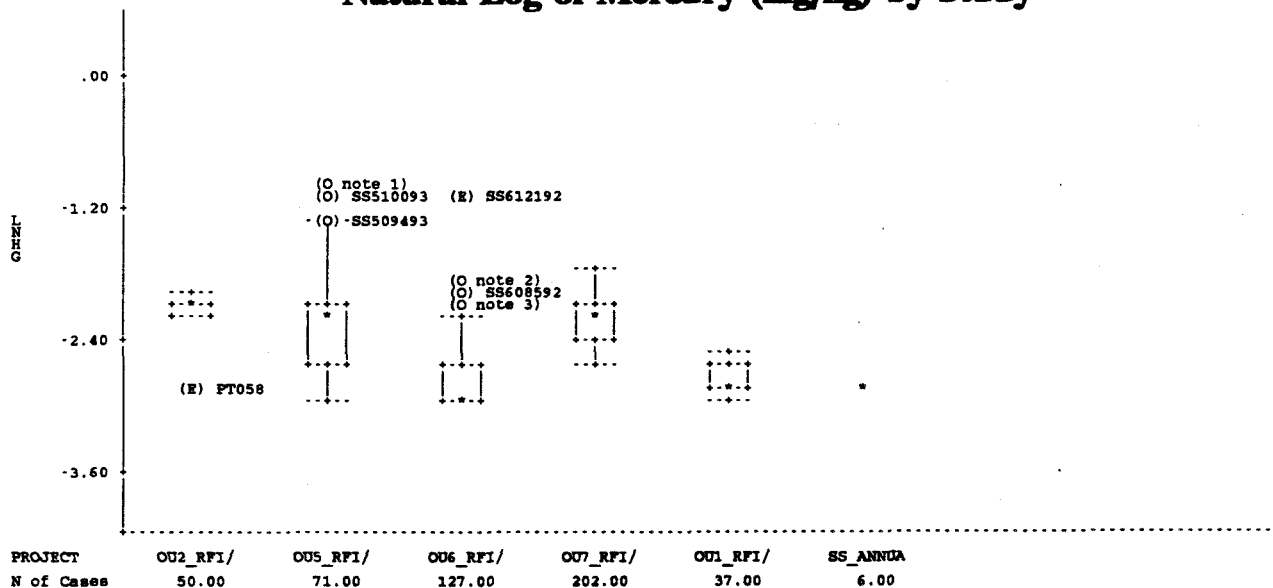
Chromium (mg/kg) by Soil Type/Study



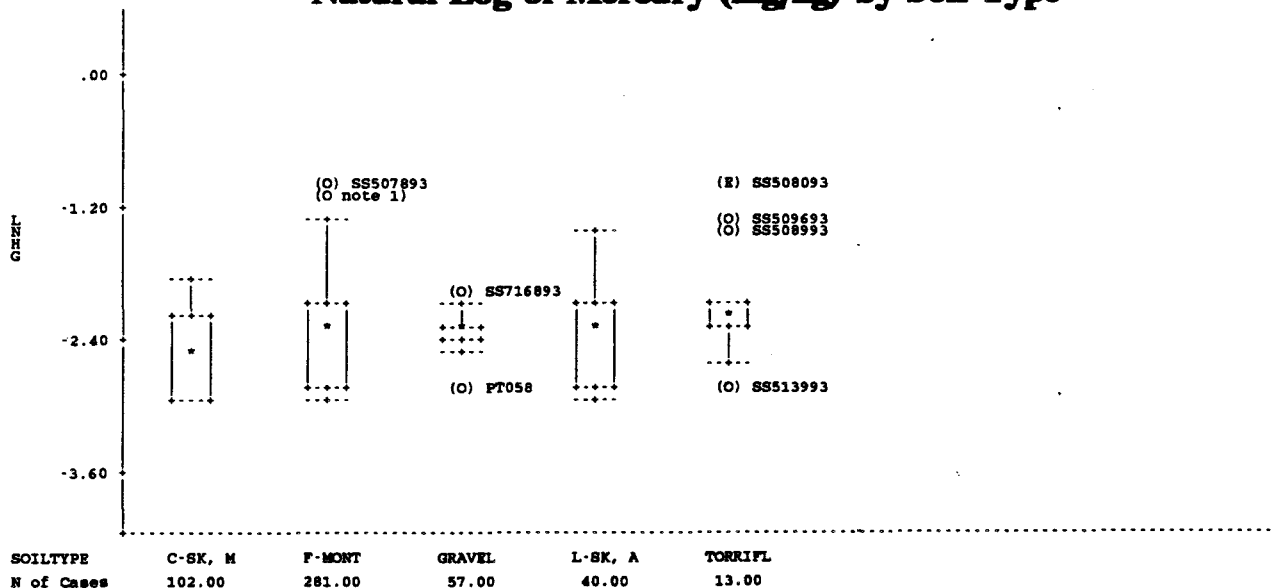
Natural Log of Mercury (mg/kg)



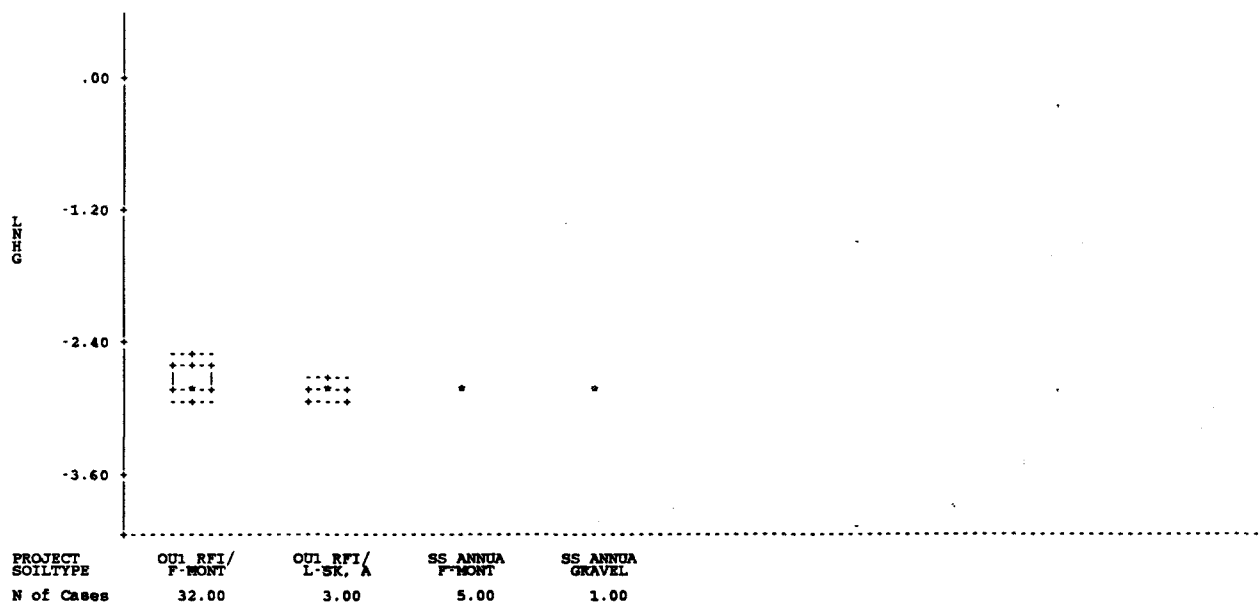
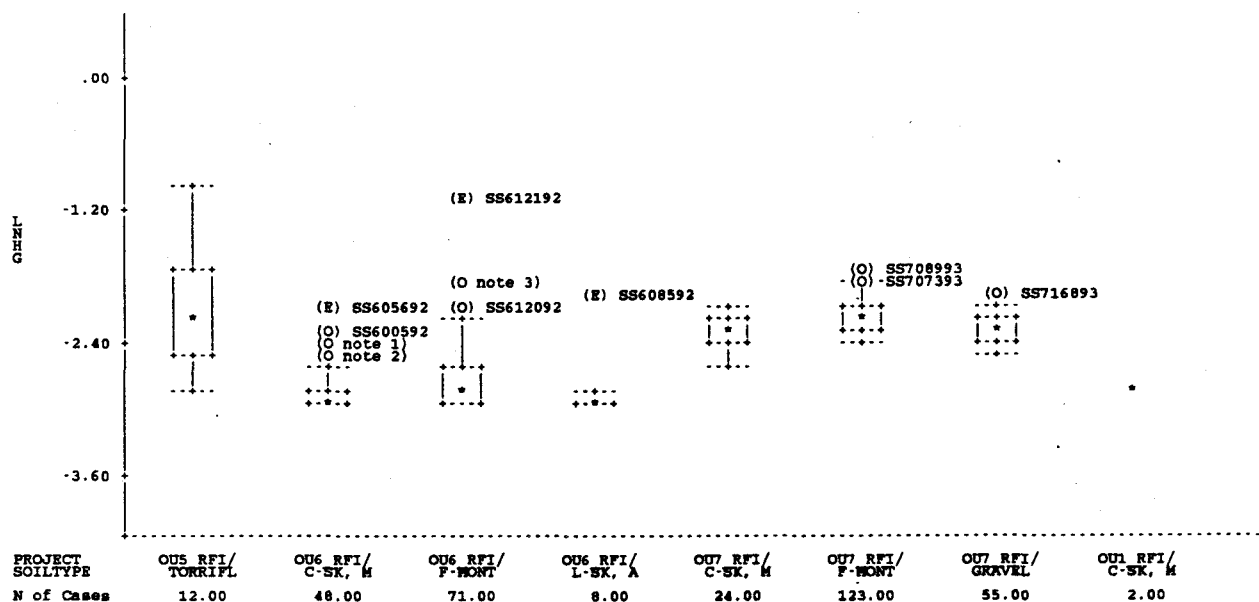
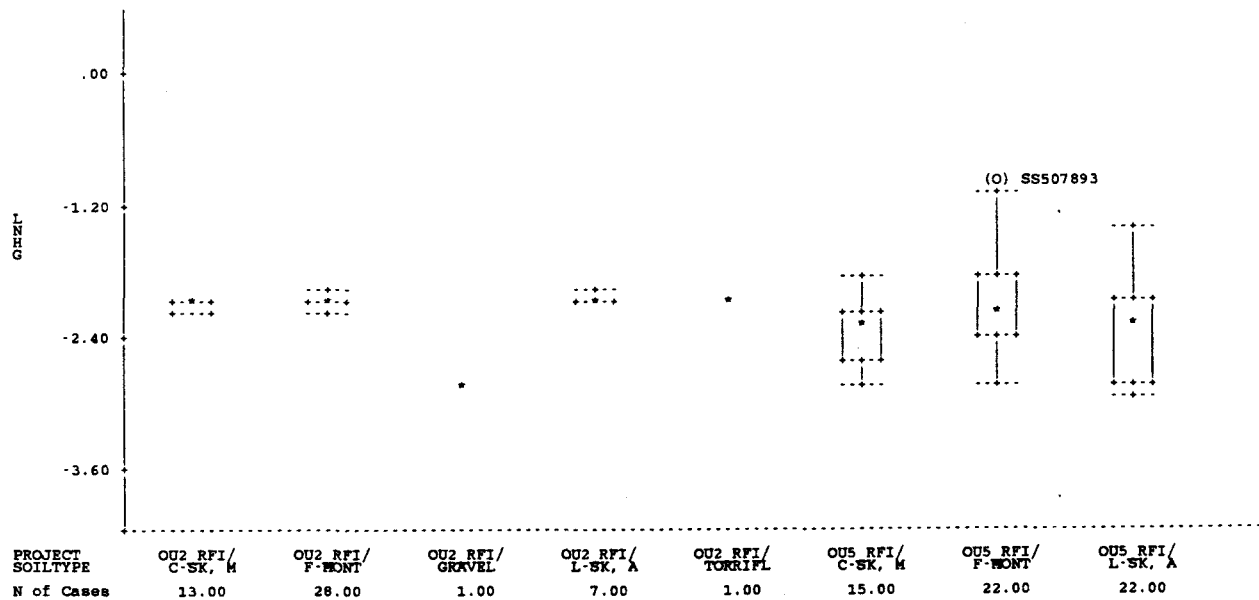
Natural Log of Mercury (mg/kg) by Study



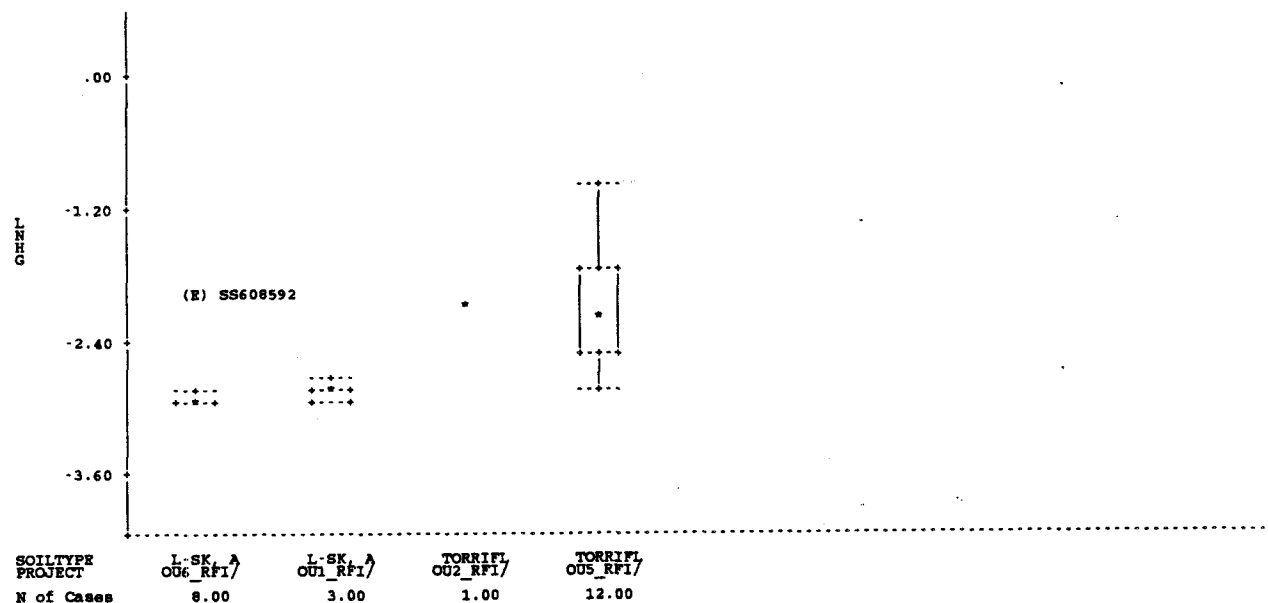
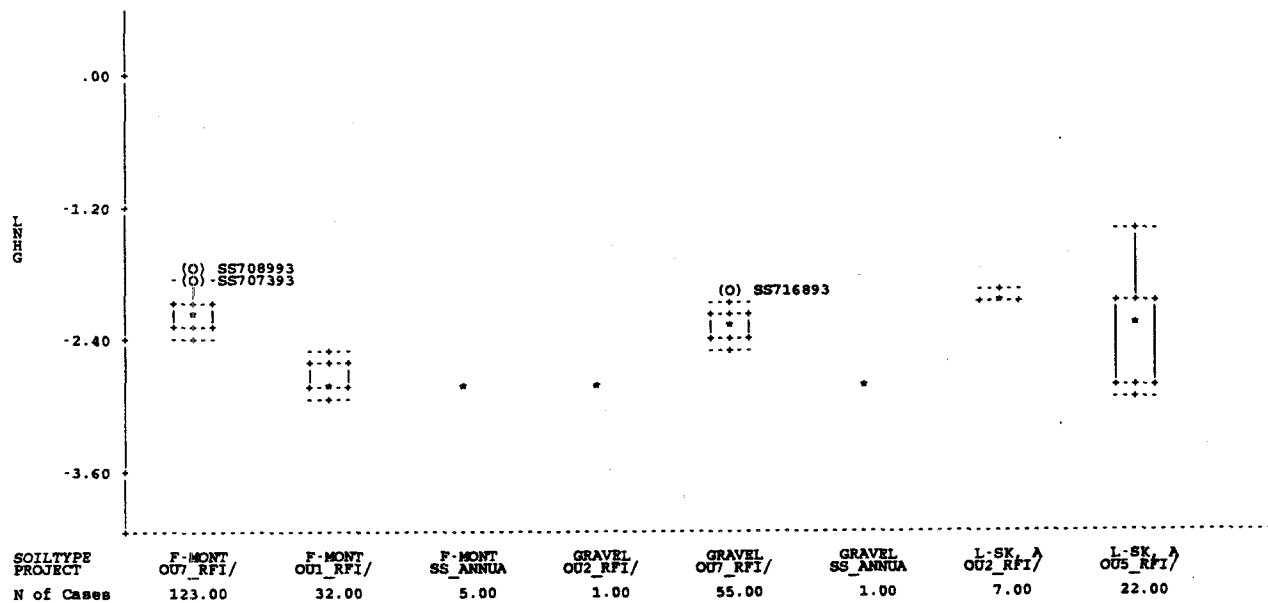
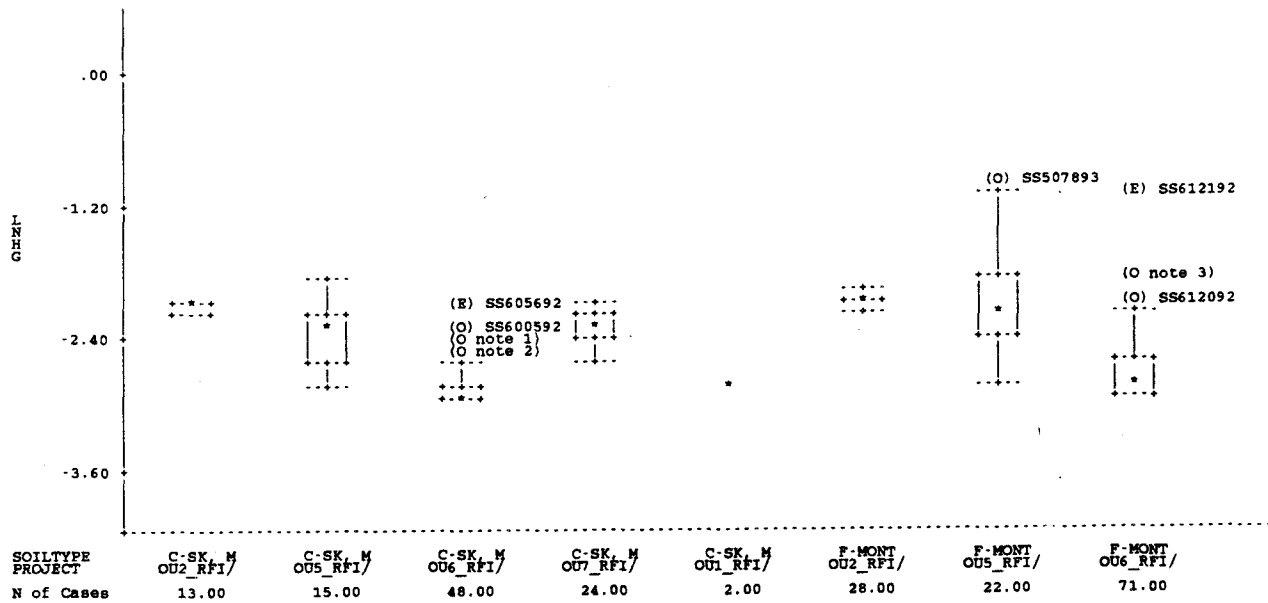
Natural Log of Mercury (mg/kg) by Soil Type



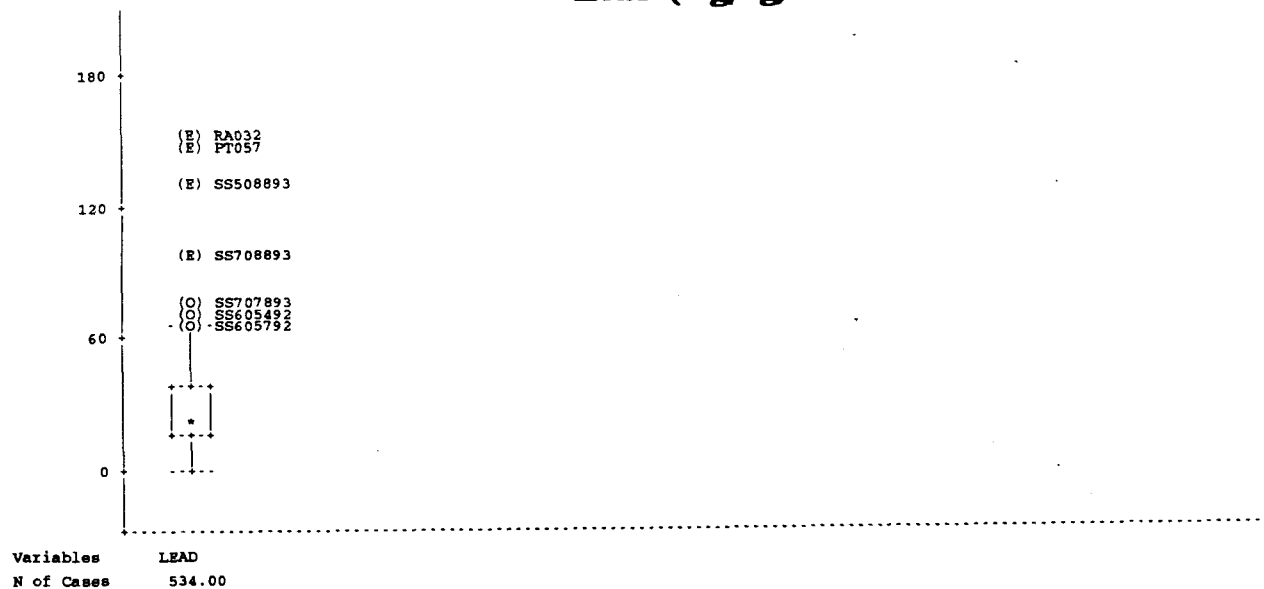
Natural Log of Mercury (mg/kg) by Study/Soil Type



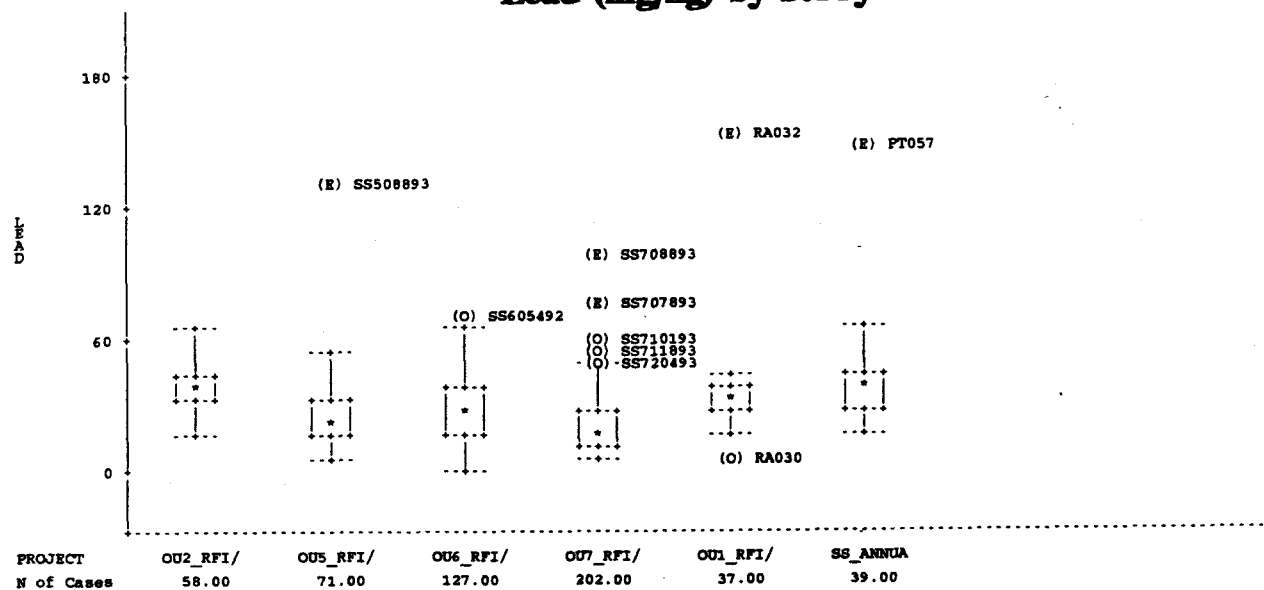
Natural Log of Mercury (mg/kg) by Soil Type/Study



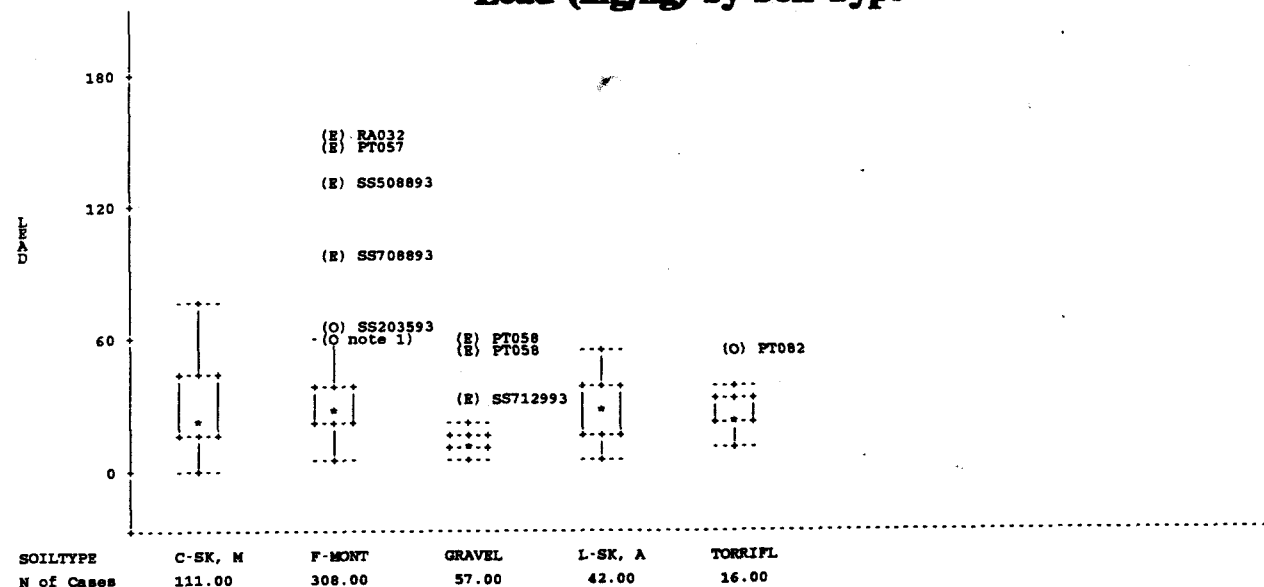
Lead (mg/kg)



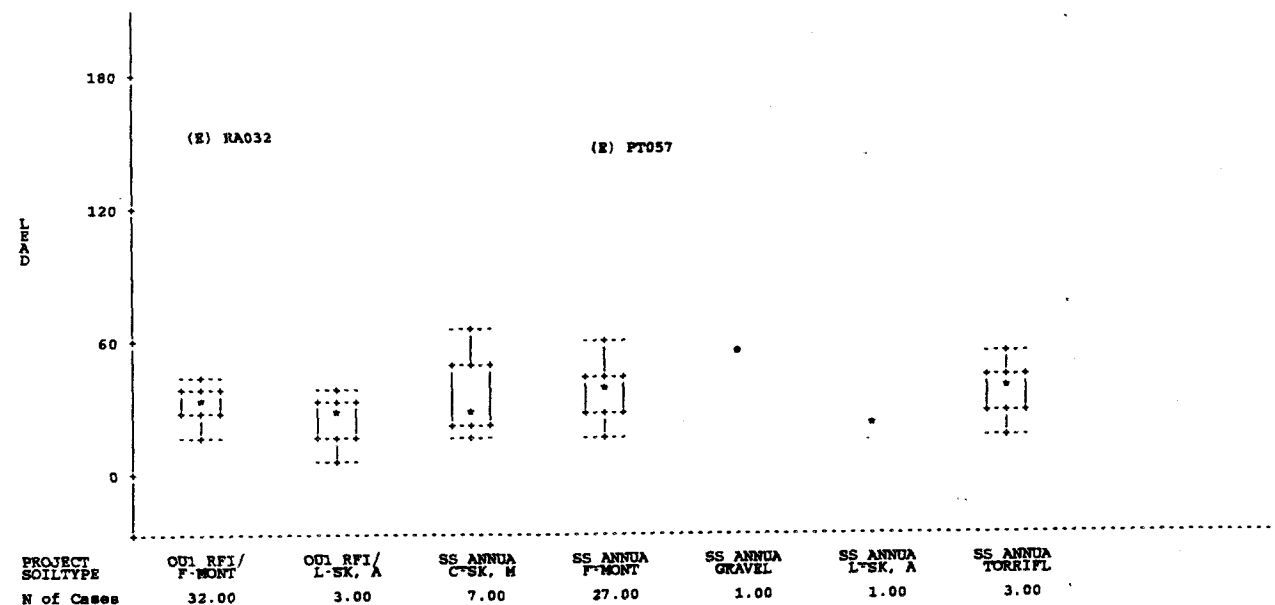
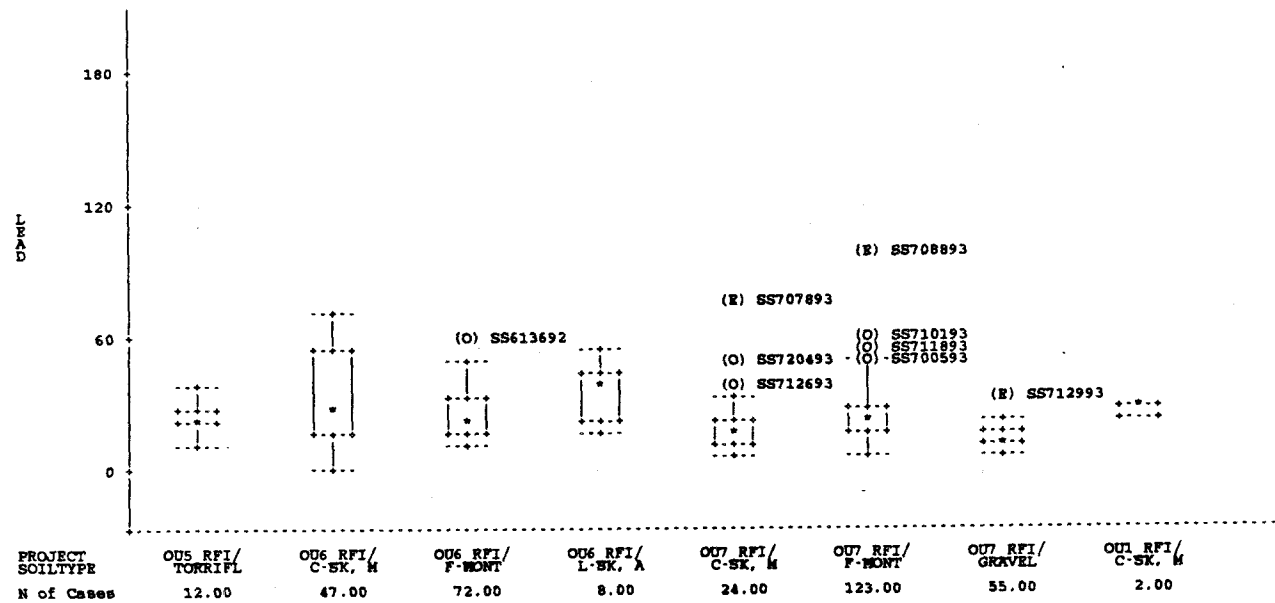
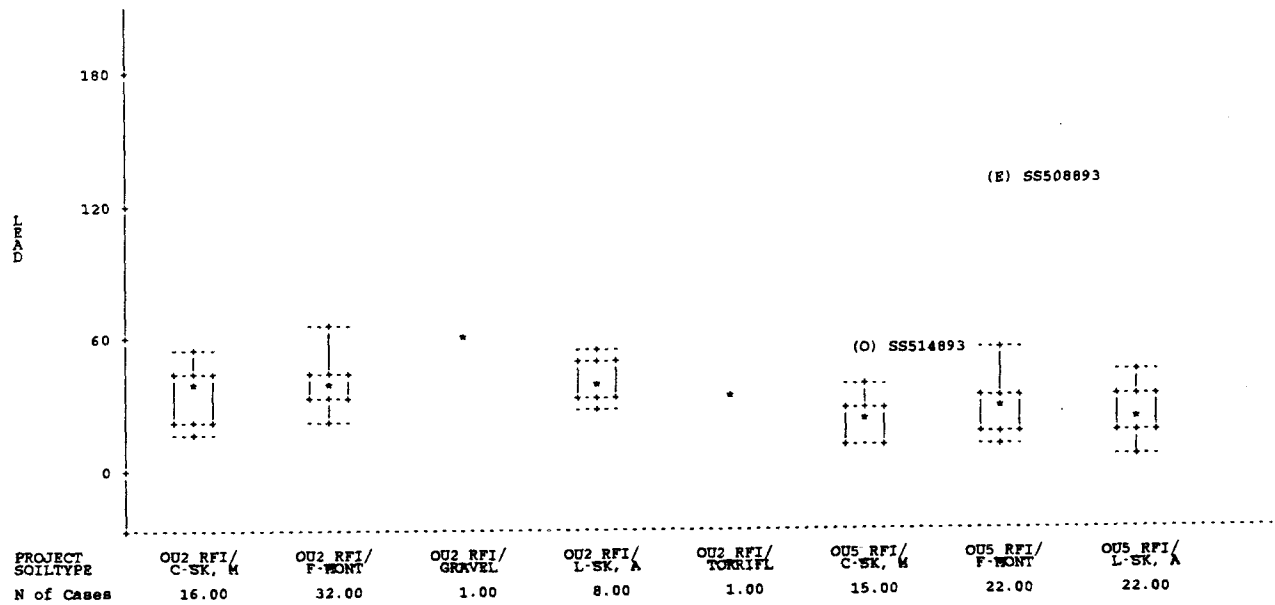
Lead (mg/kg) by Study



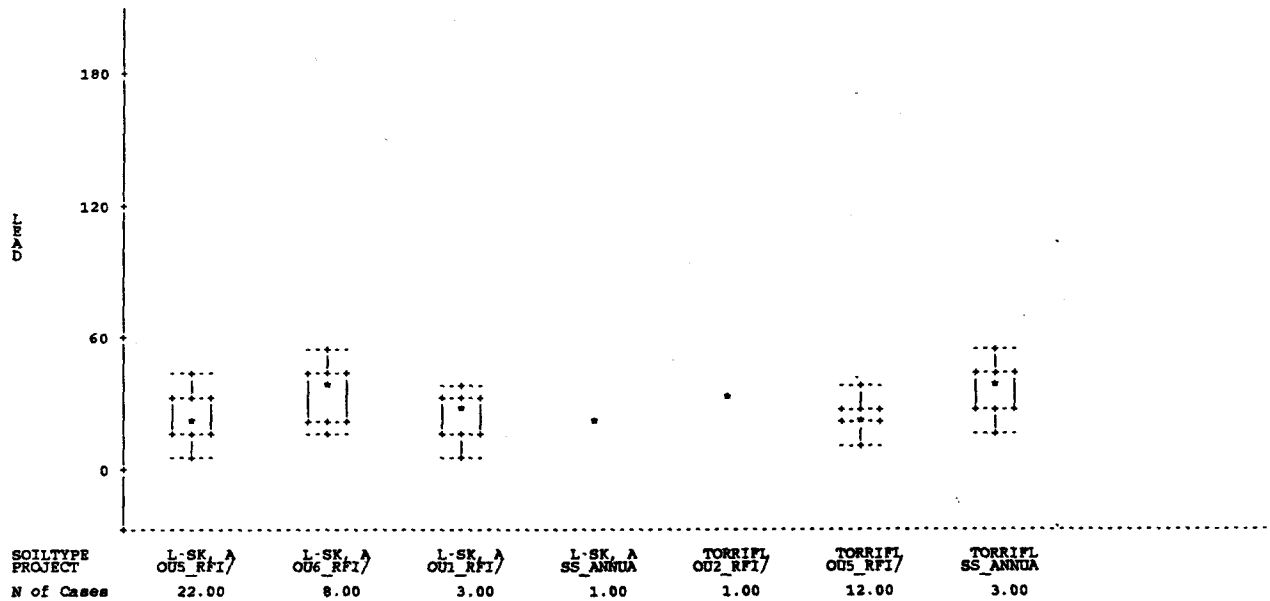
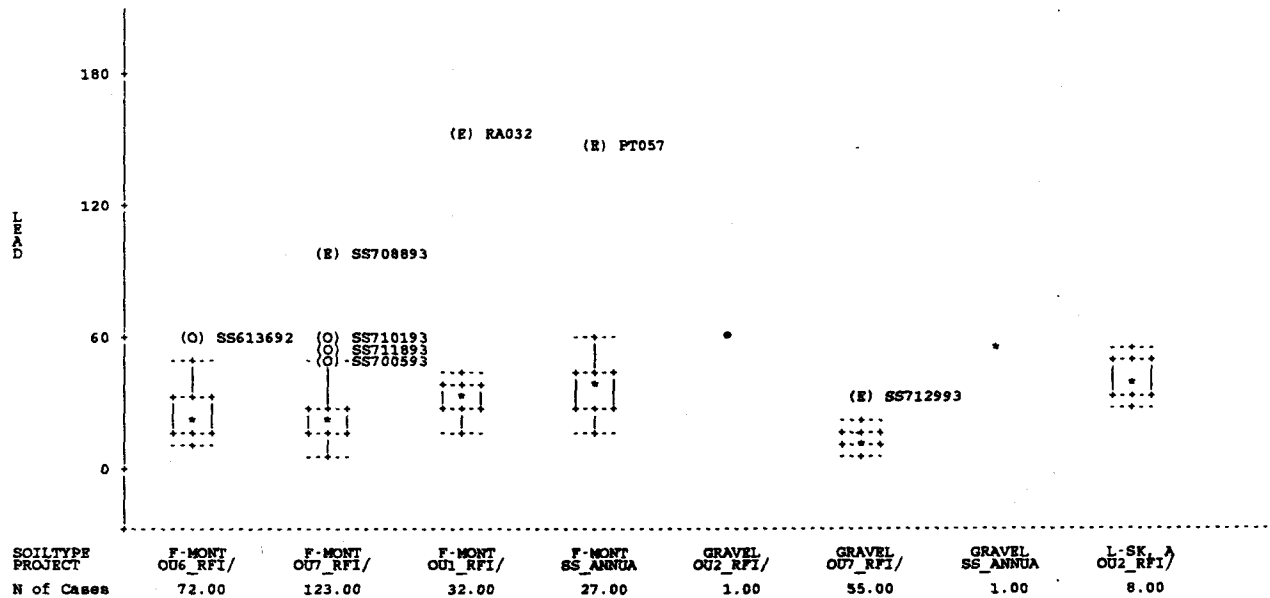
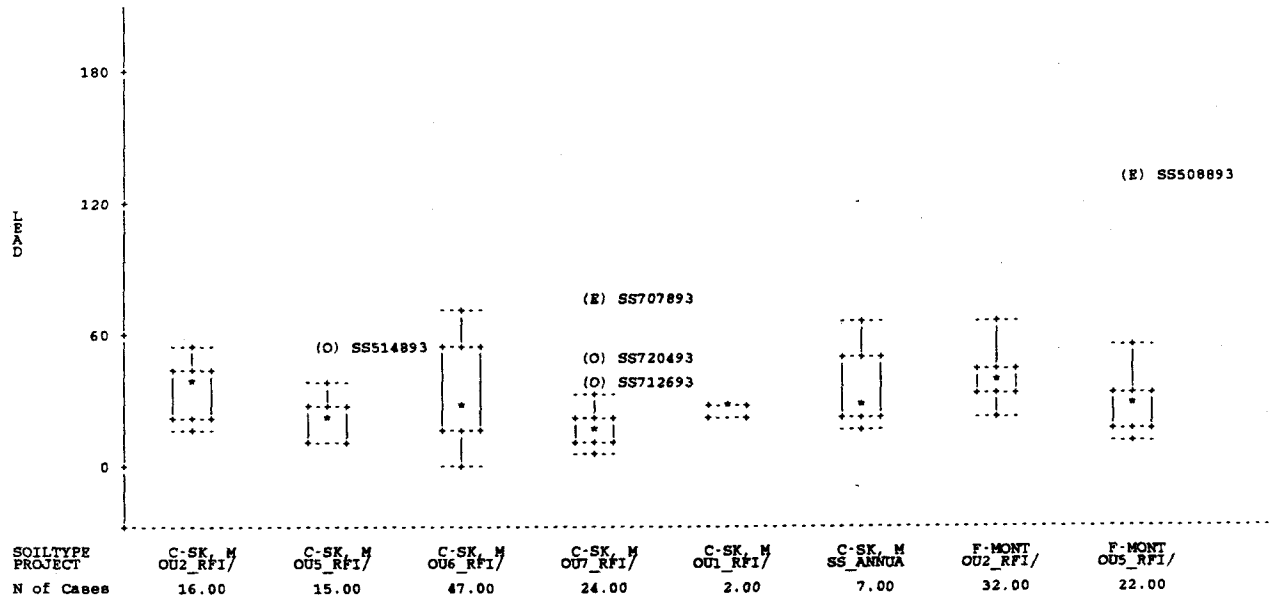
Lead (mg/kg) by Soil Type



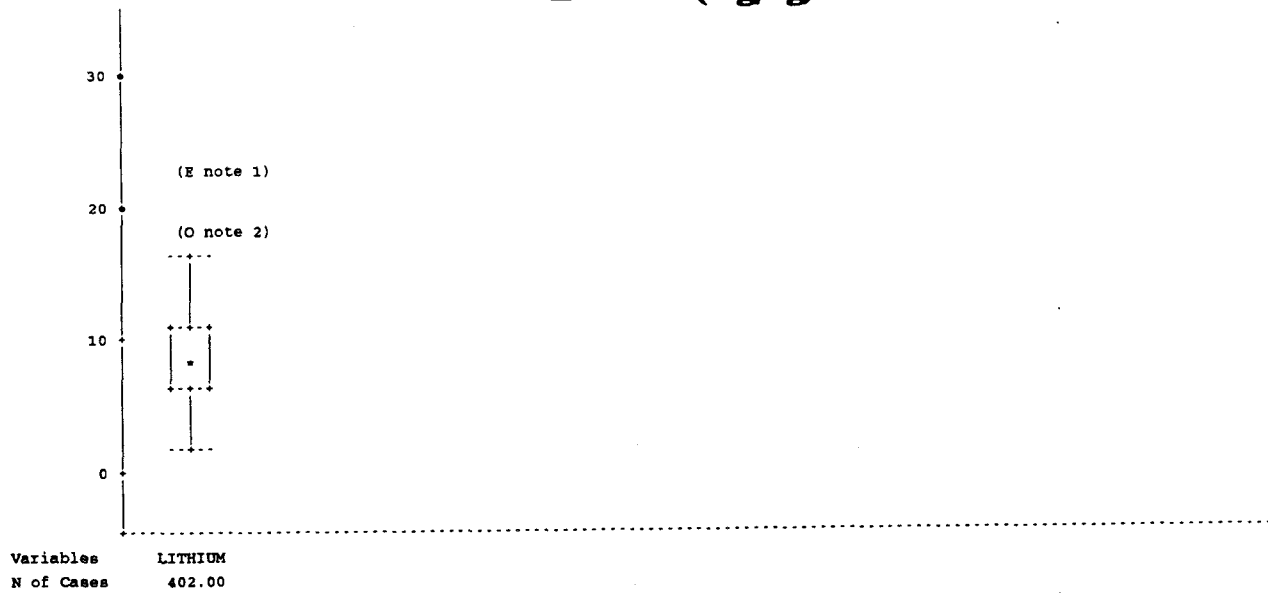
Lead (mg/kg) by Study/Soil Type



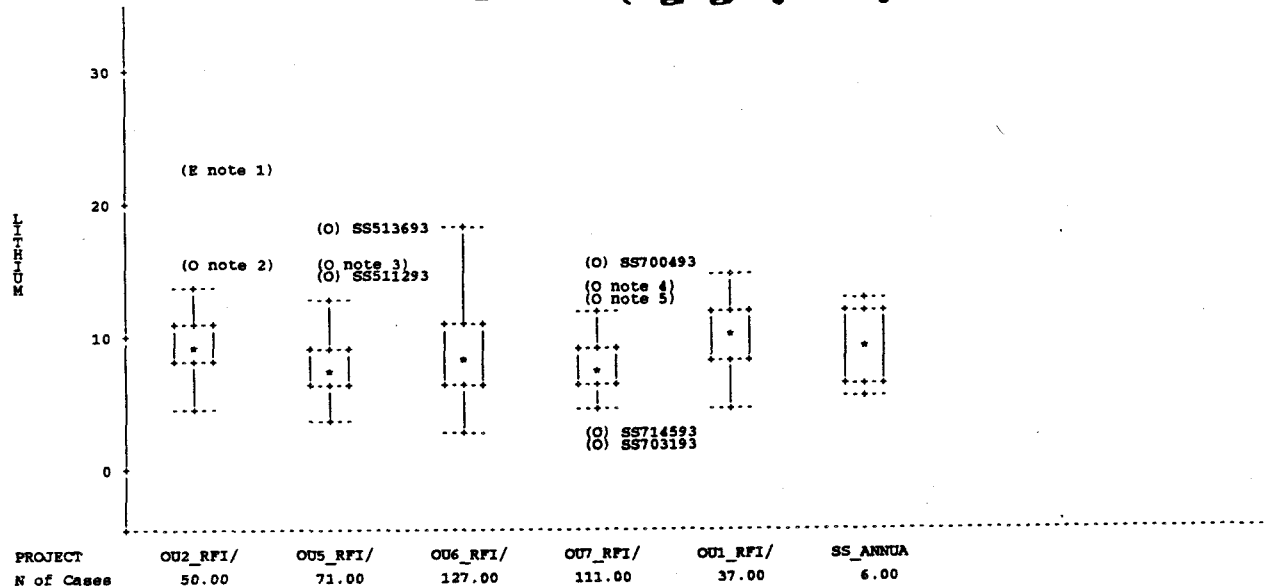
Lead (mg/kg) by Soil Type/Study



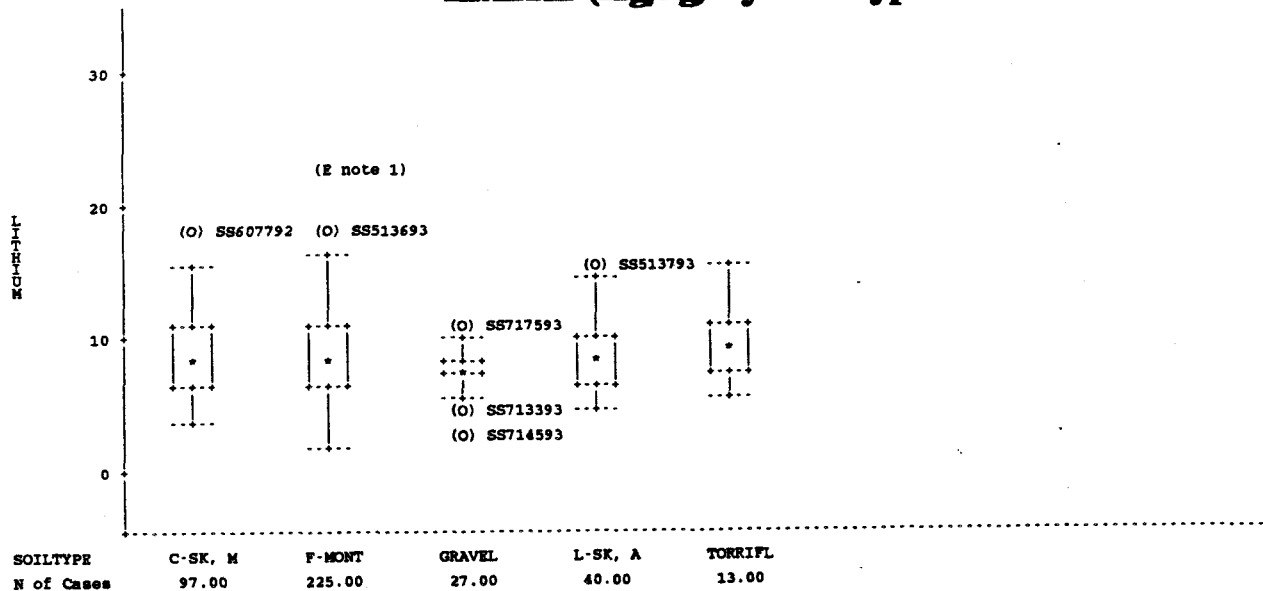
Lithium (mg/kg)



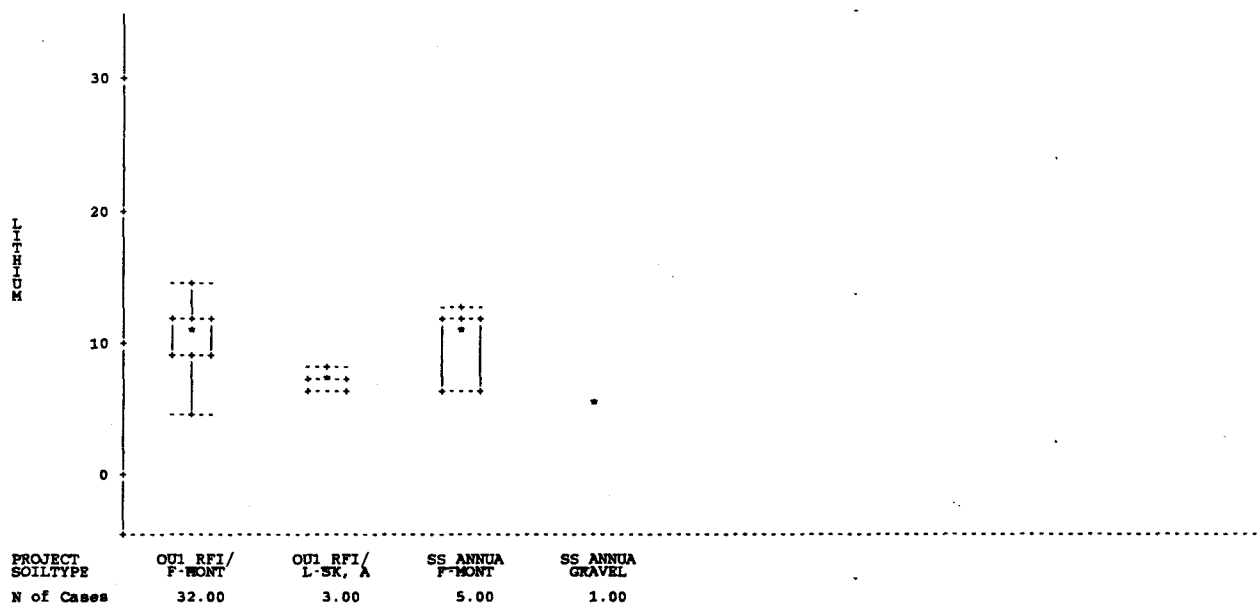
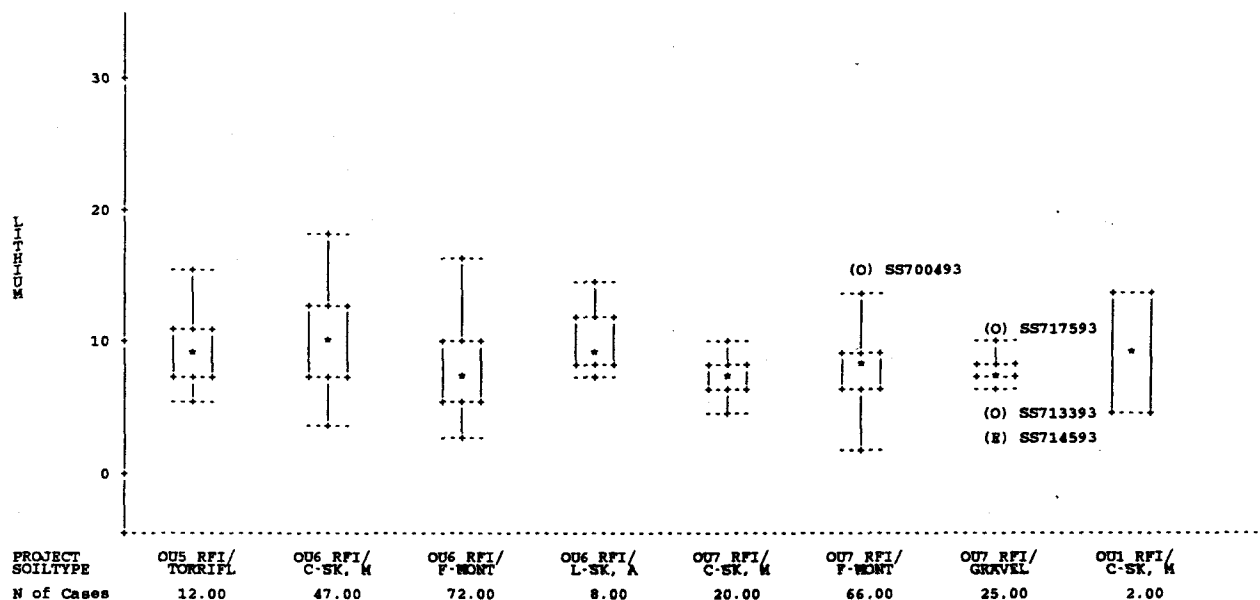
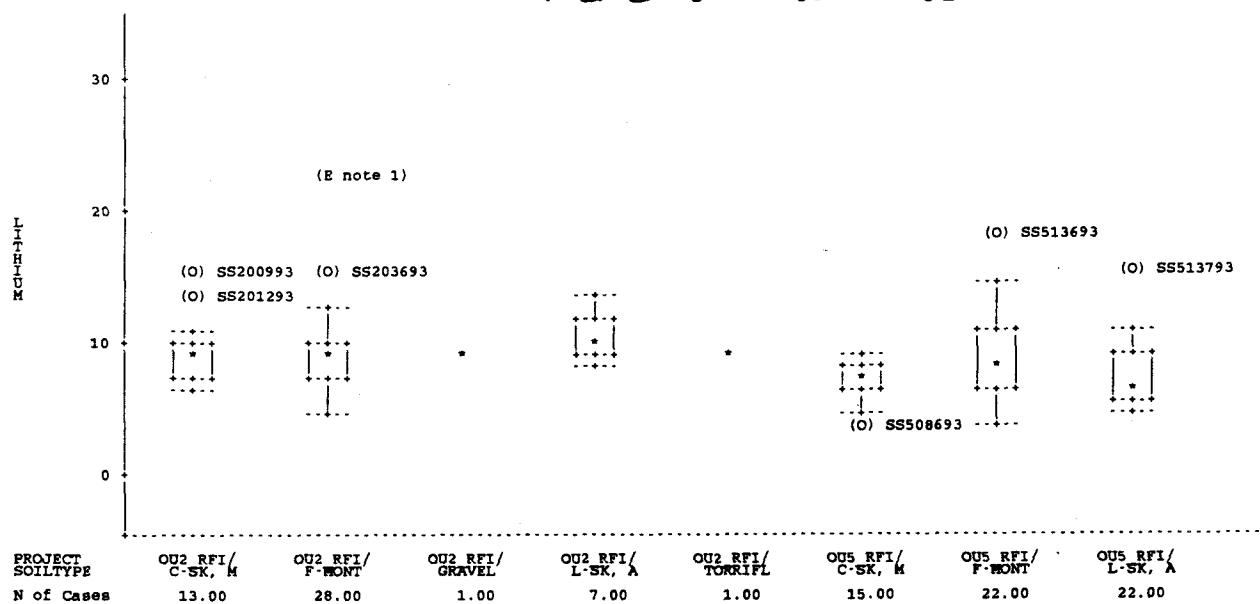
Lithium (mg/kg) by Study



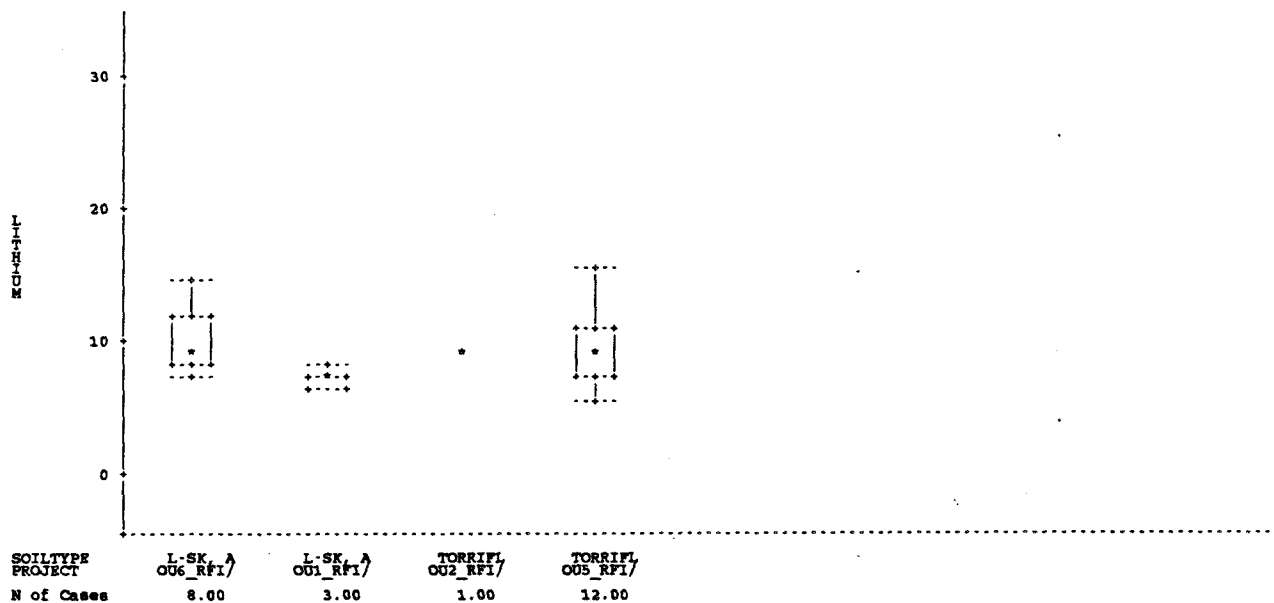
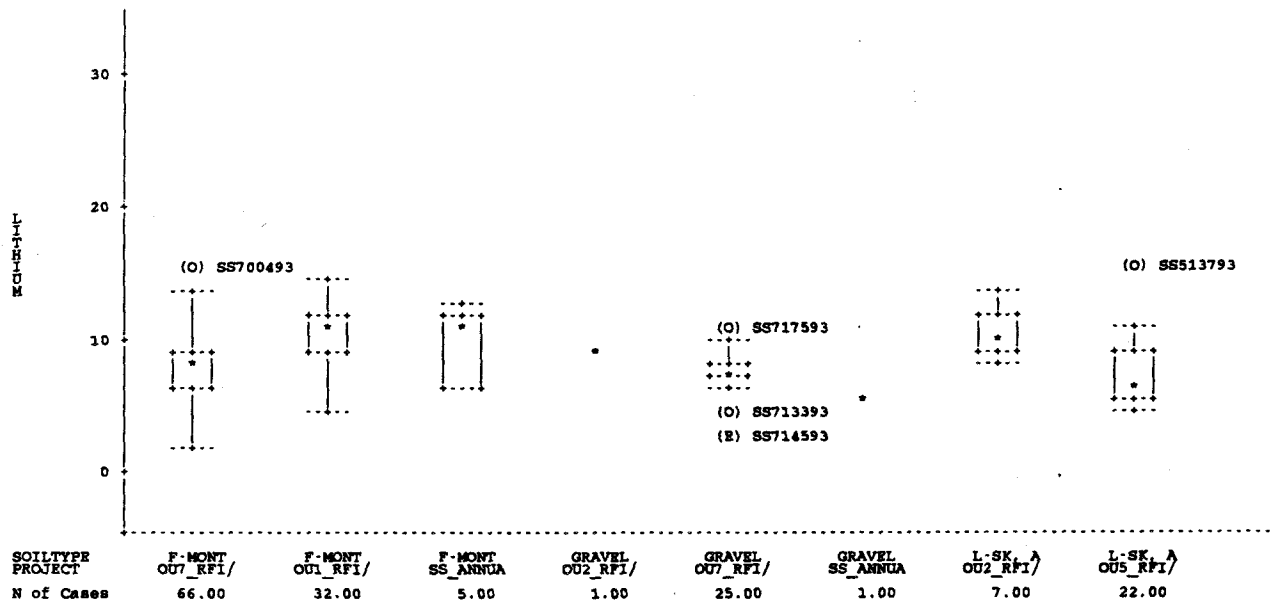
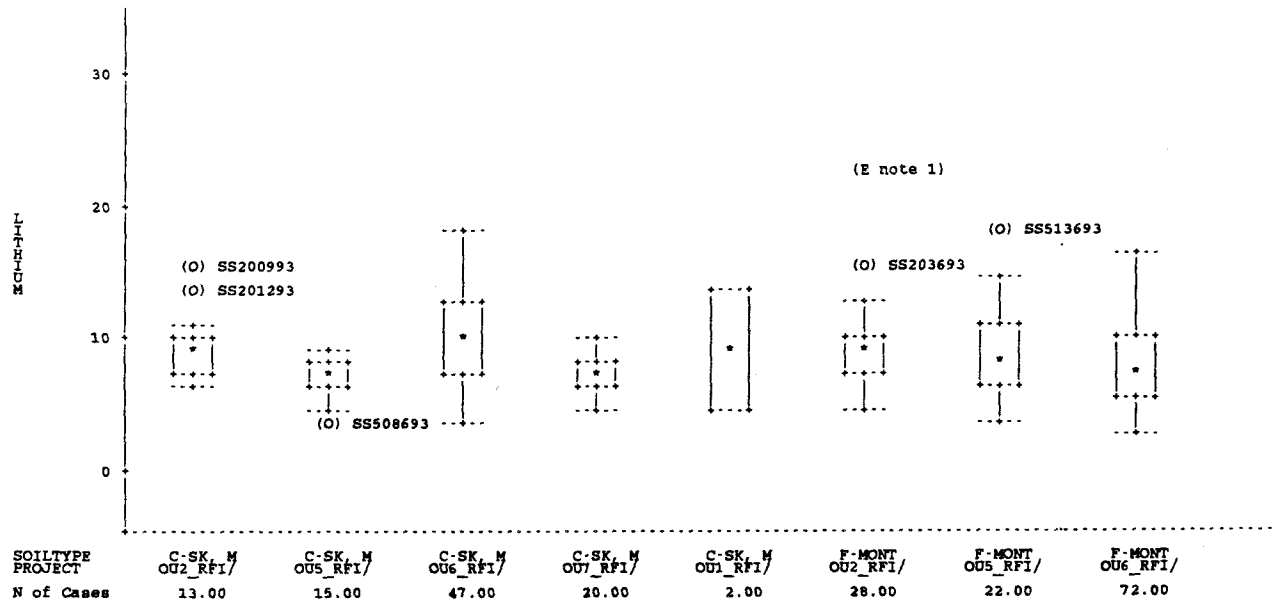
Lithium (mg/kg) by Soil Type



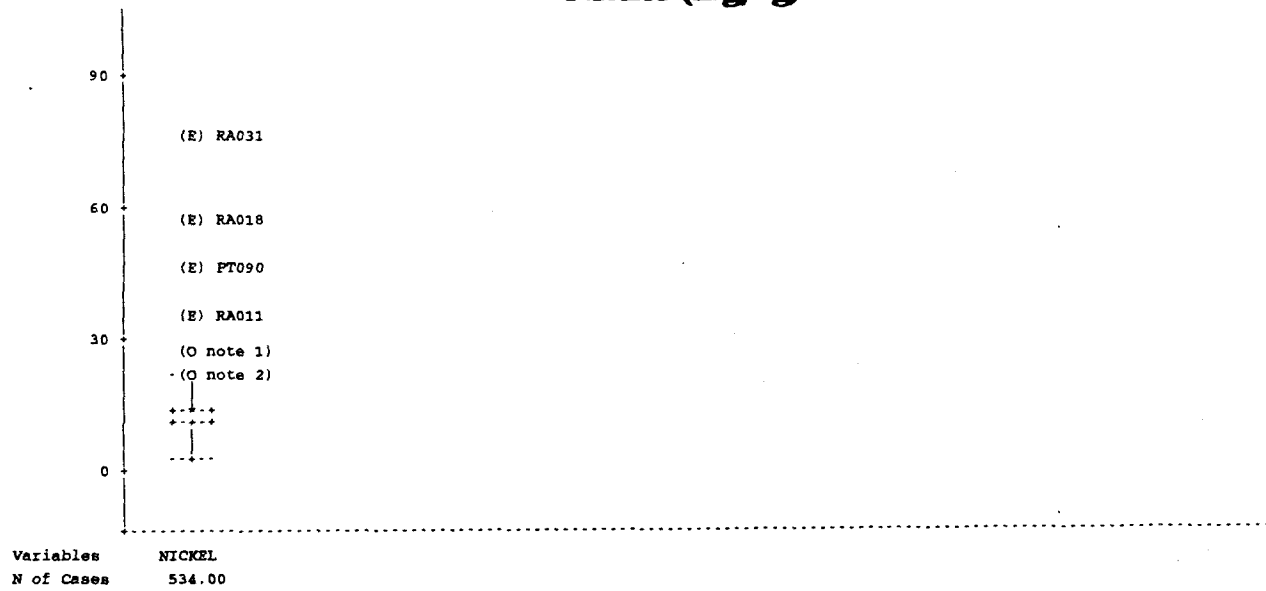
Lithium (mg/kg) by Study/Soil Type



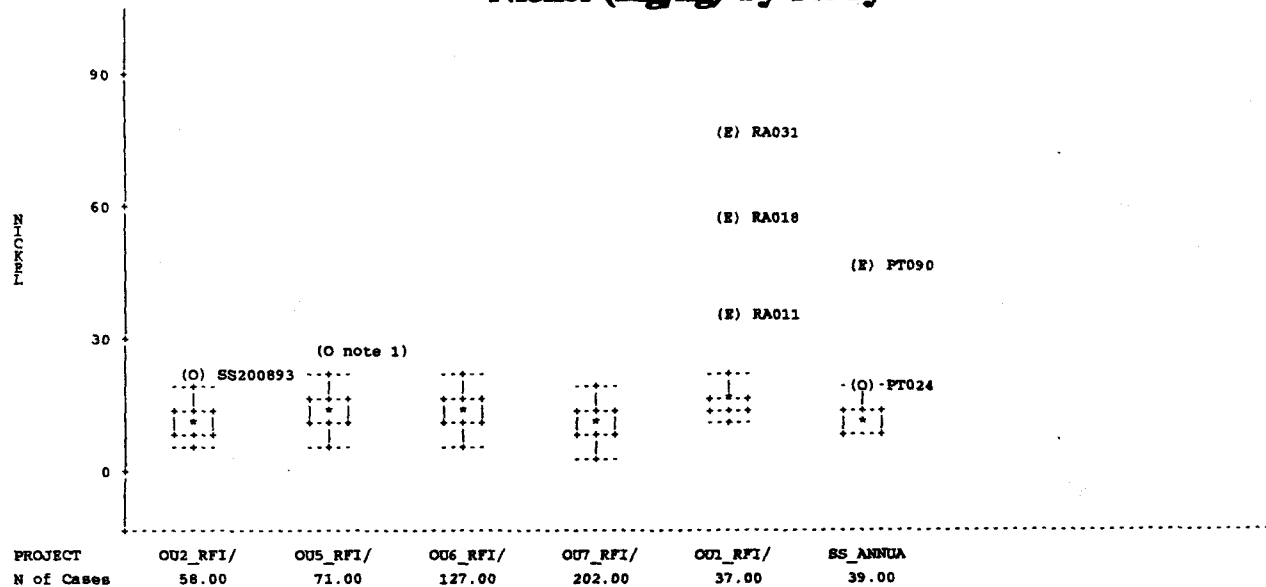
Lithium (mg/kg) by Soil Type/Study



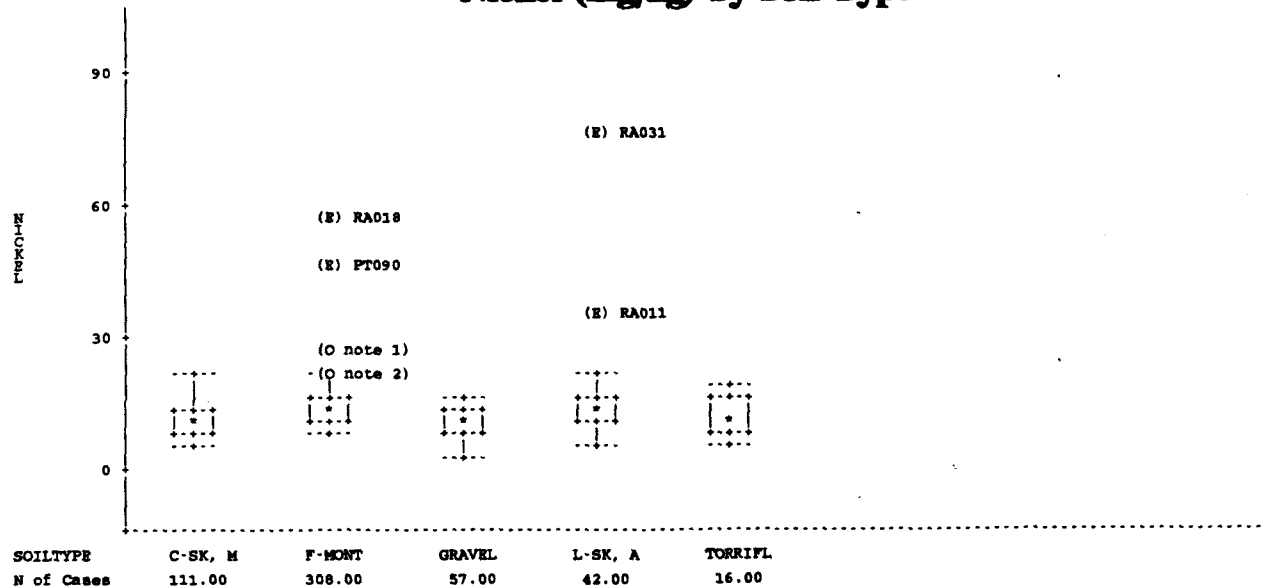
Nickel (mg/kg)



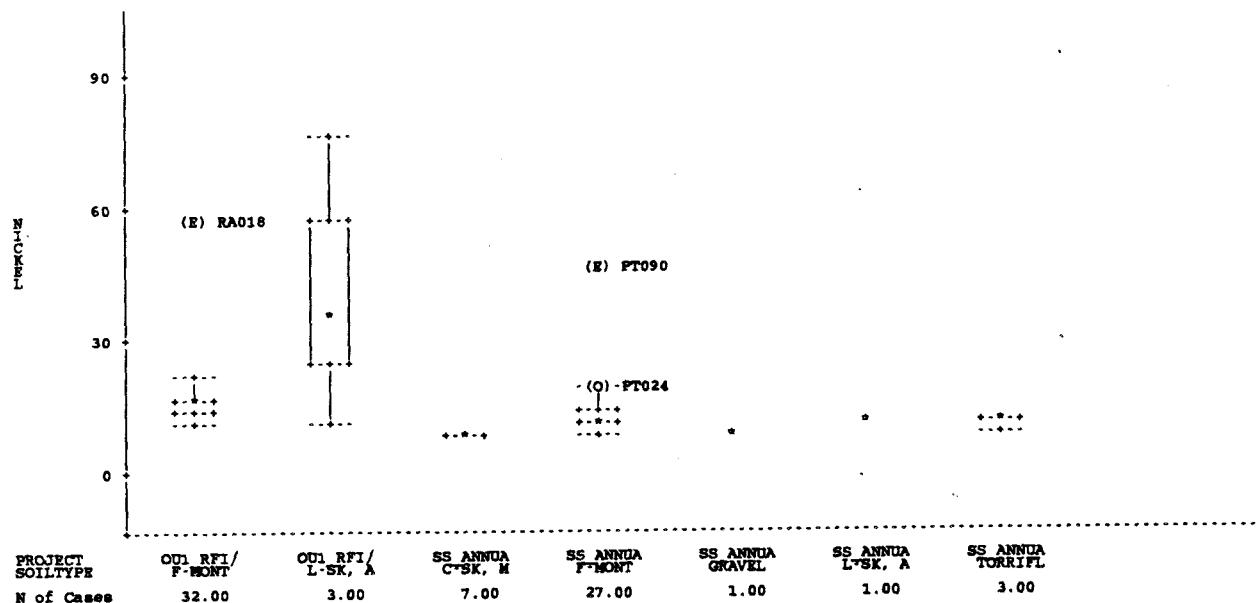
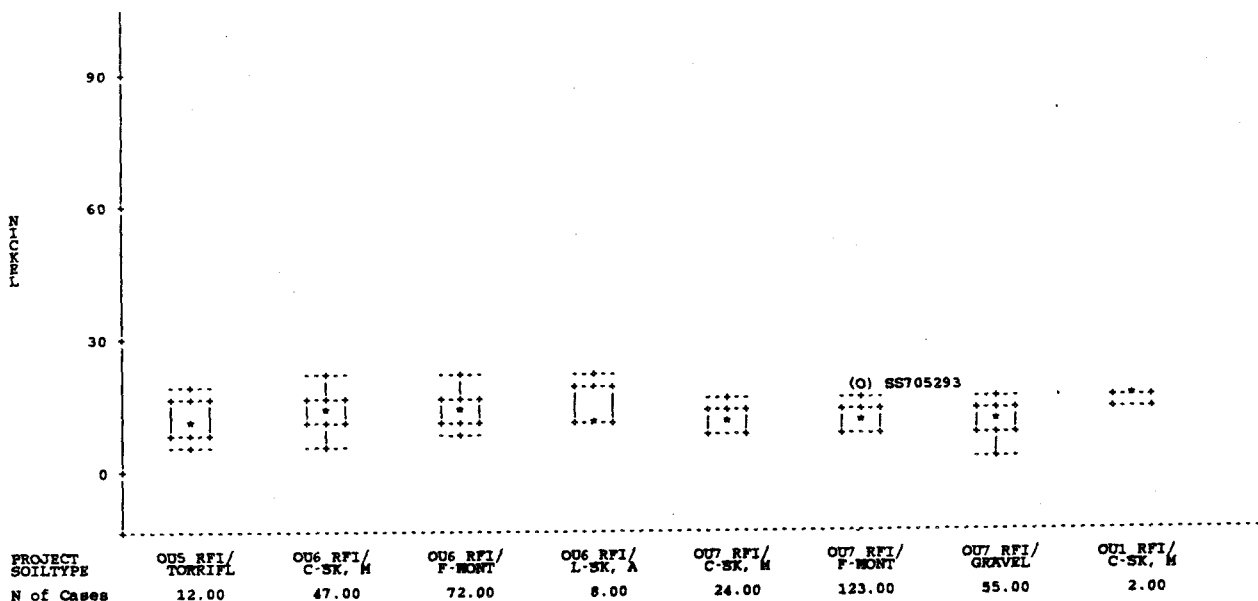
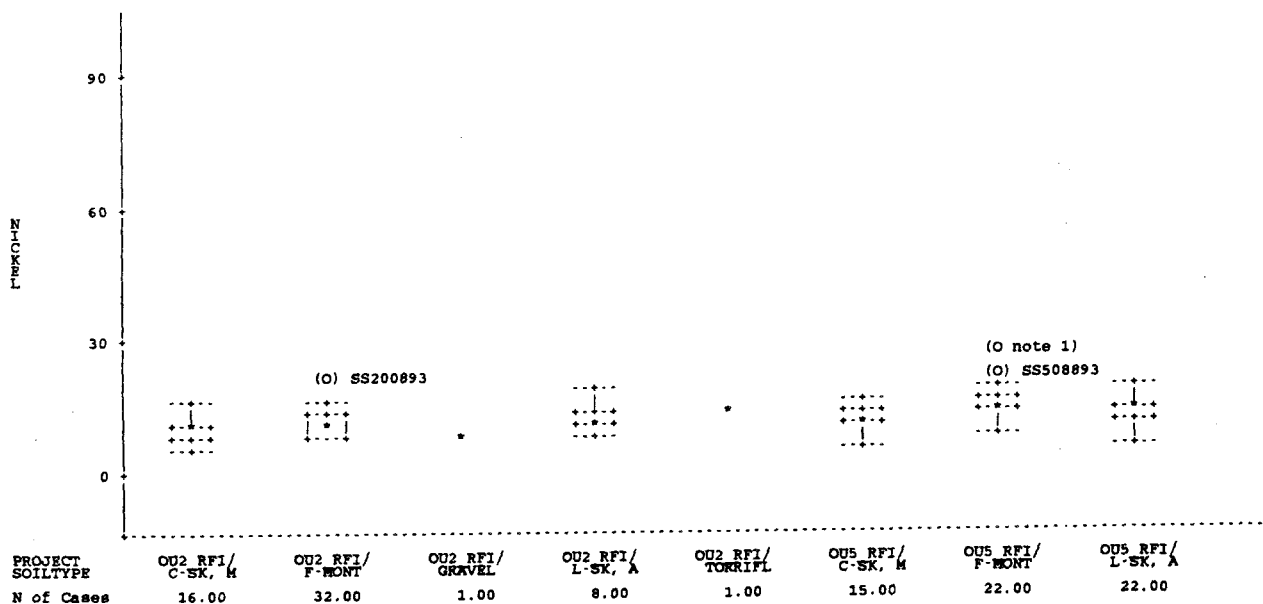
Nickel (mg/kg) by Study



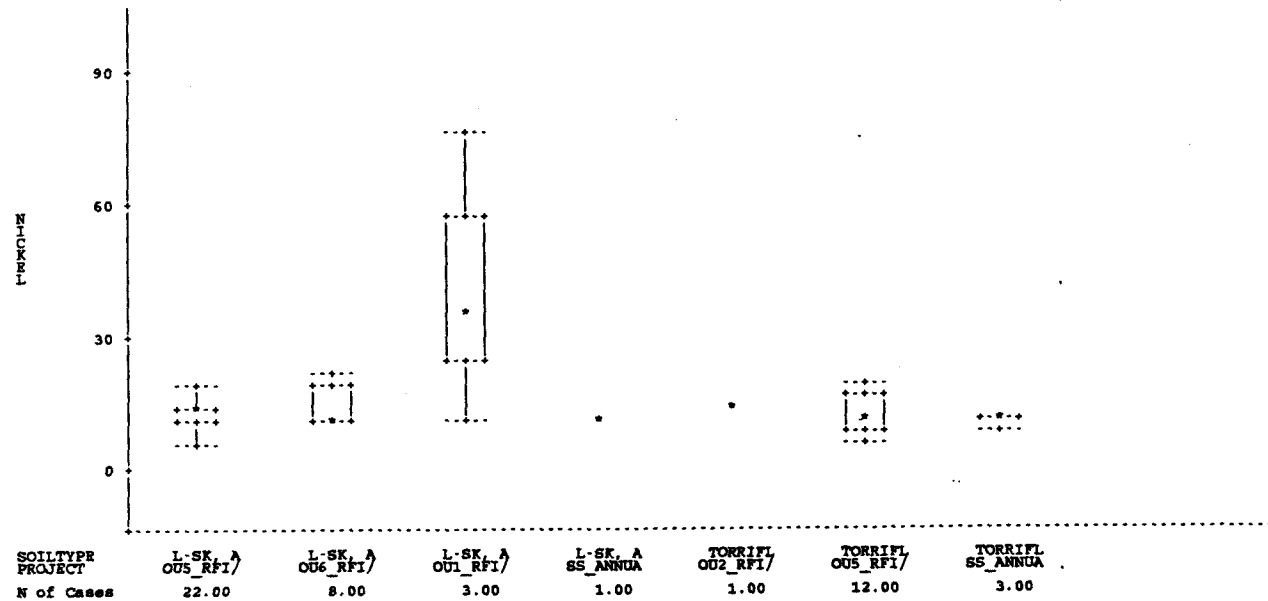
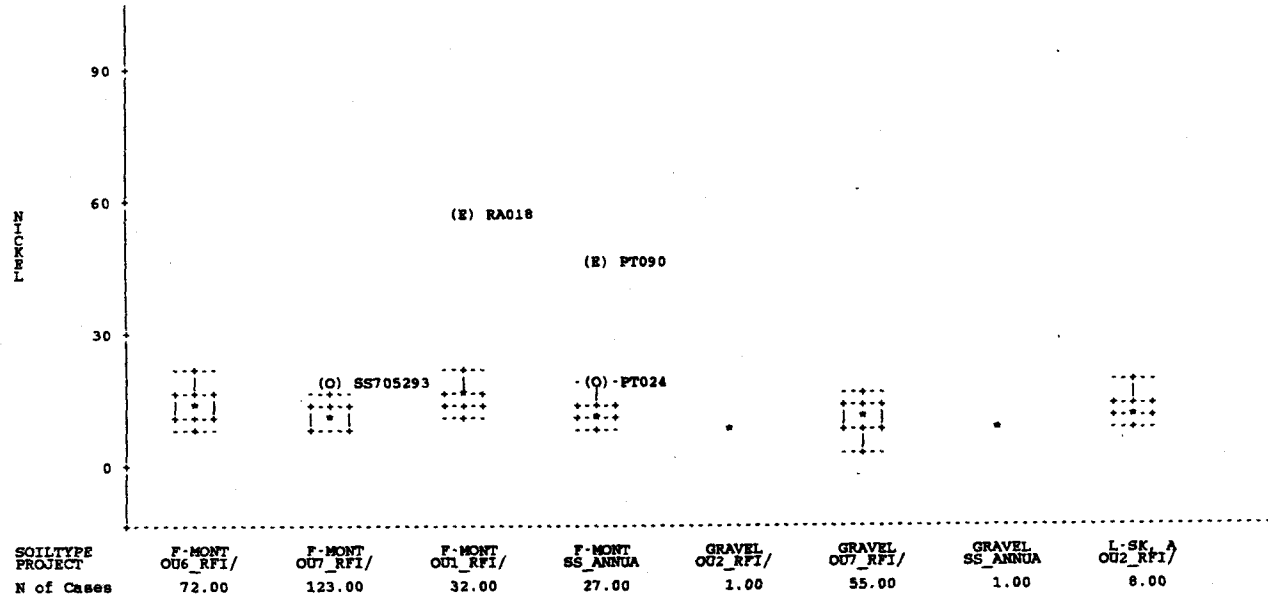
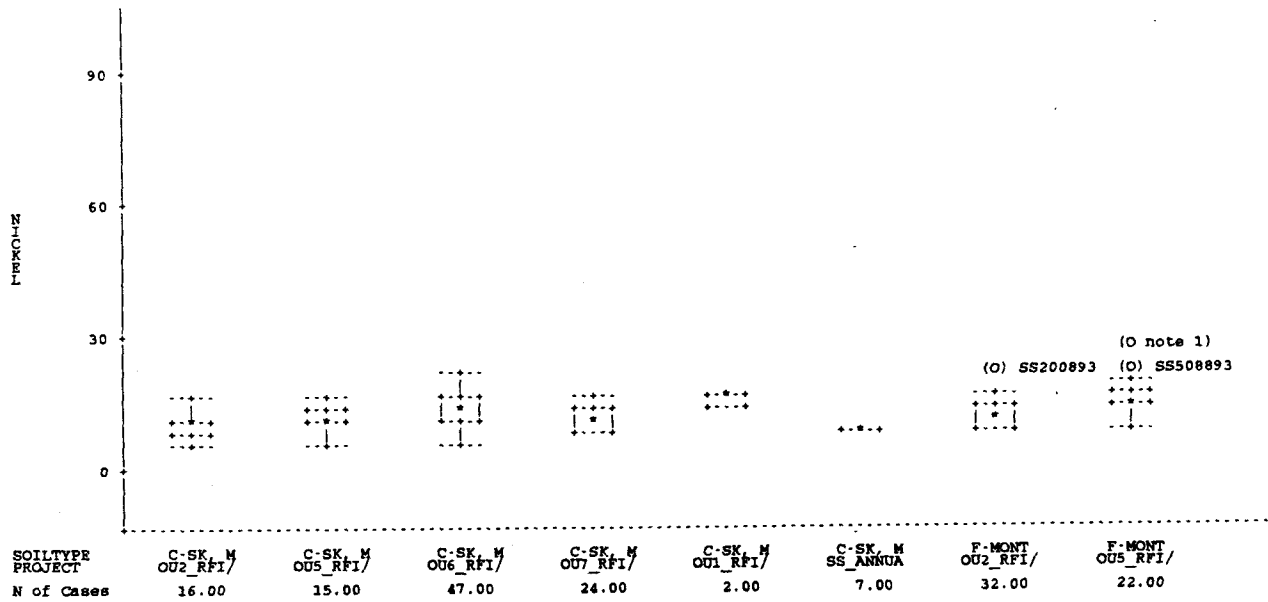
Nickel (mg/kg) by Soil Type



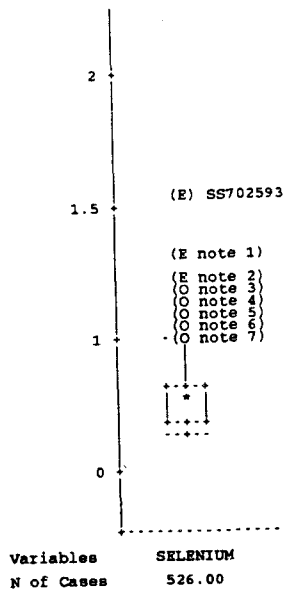
Nickel (mg/kg) by Study/Soil Type



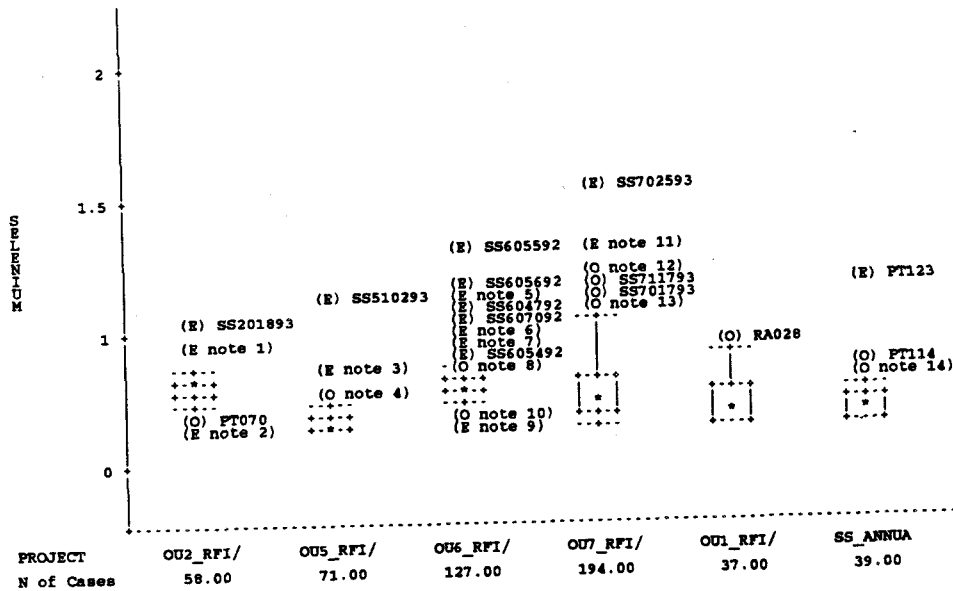
Nickel (mg/kg) by Soil Type/Study



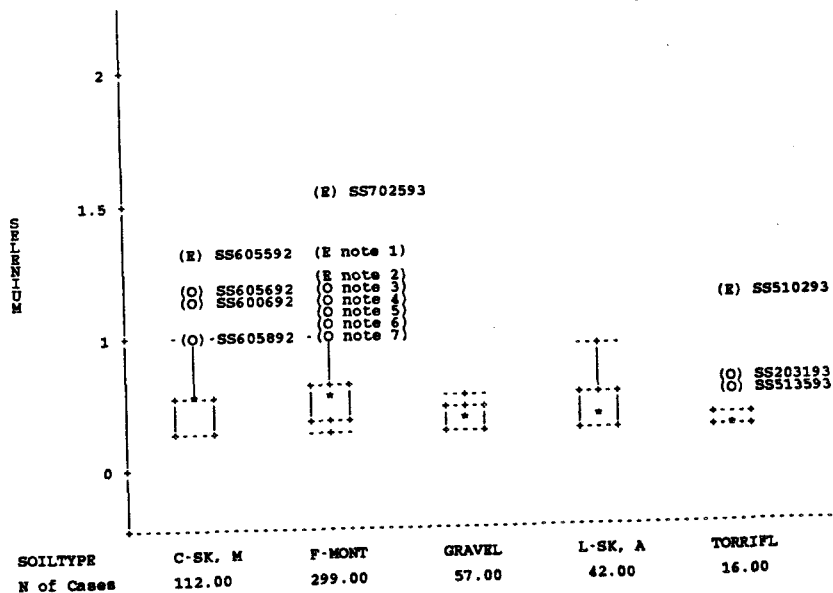
Selenium (mg/kg)



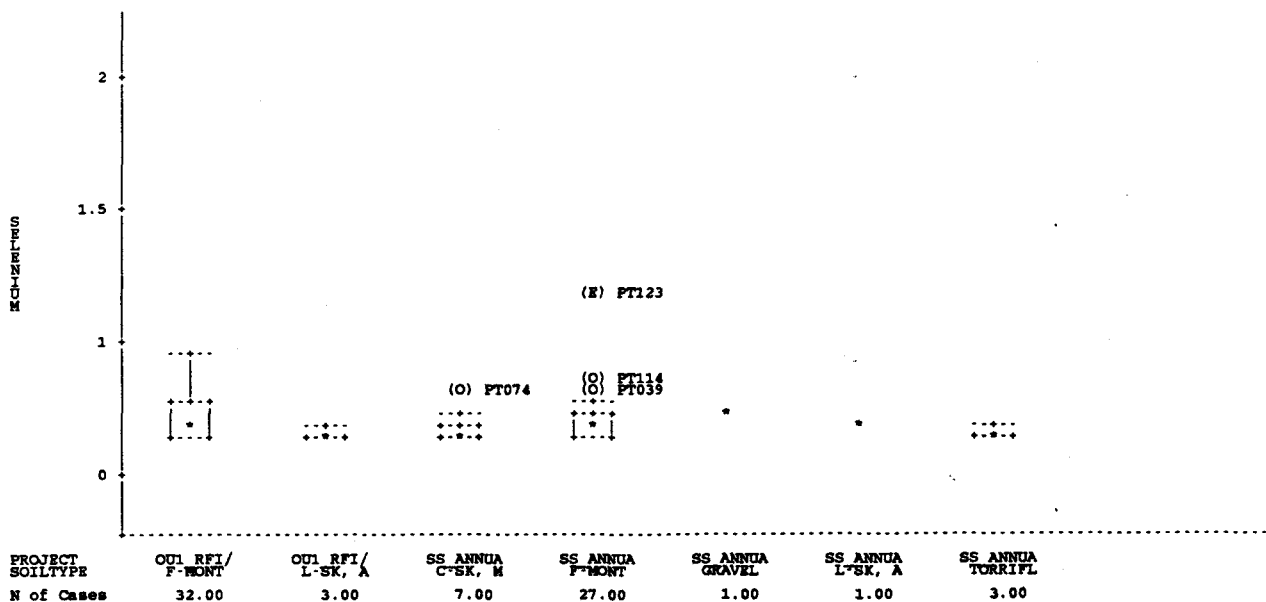
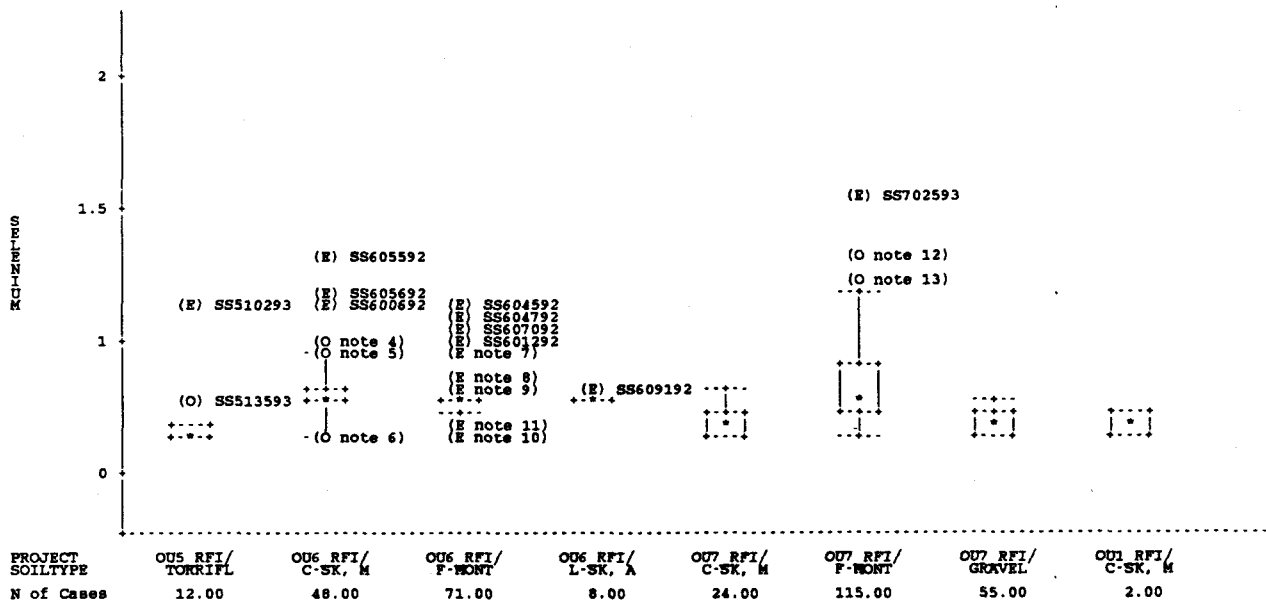
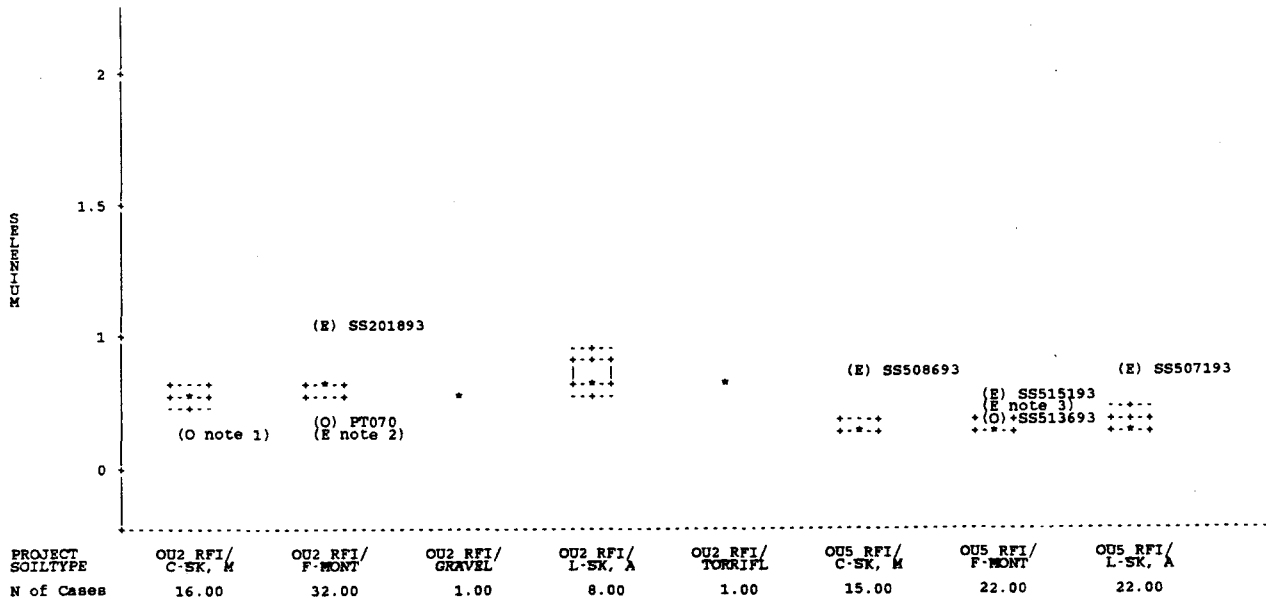
Selenium (mg/kg) by Study



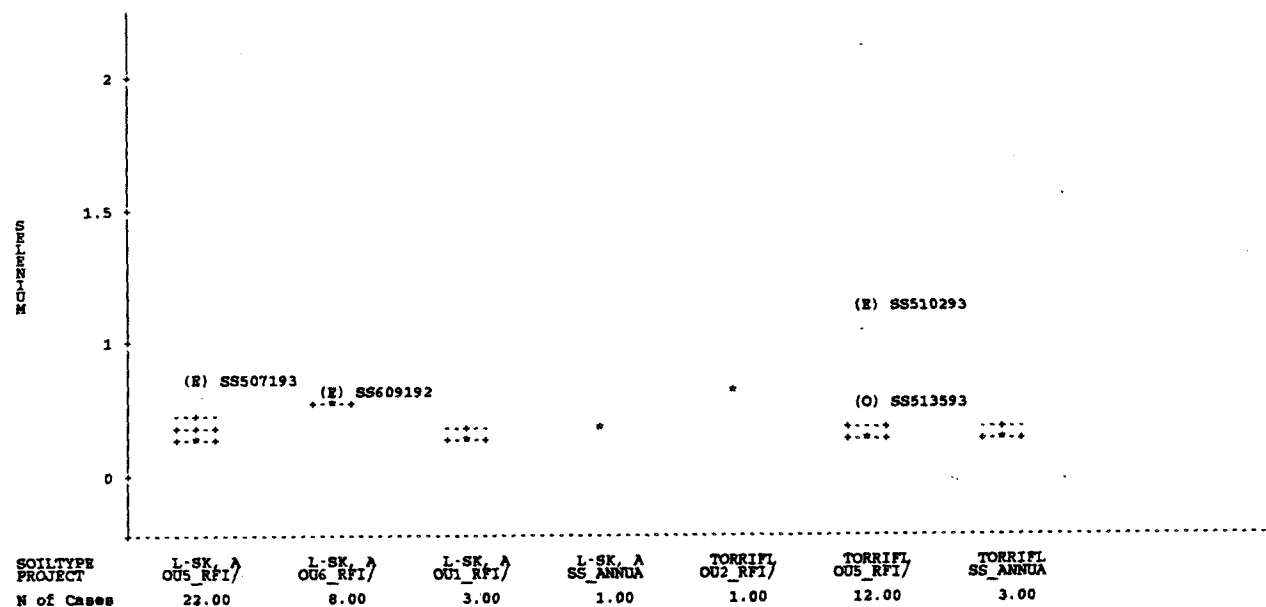
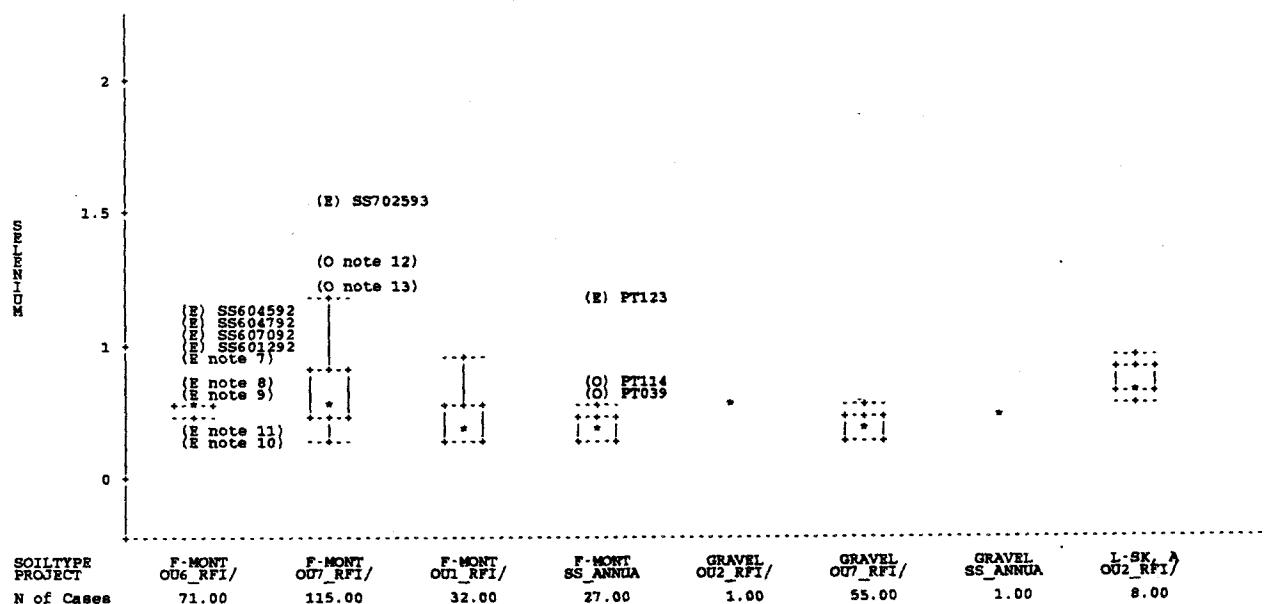
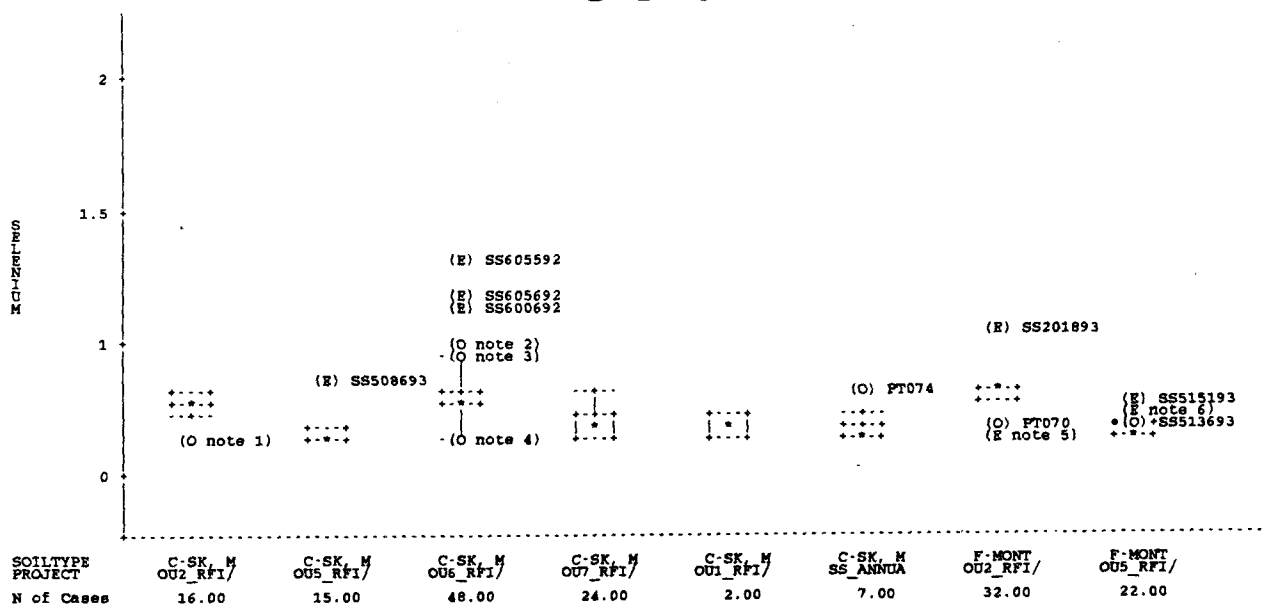
Selenium (mg/kg) by Soil Type



Selenium (mg/kg) by Study/Soil Type



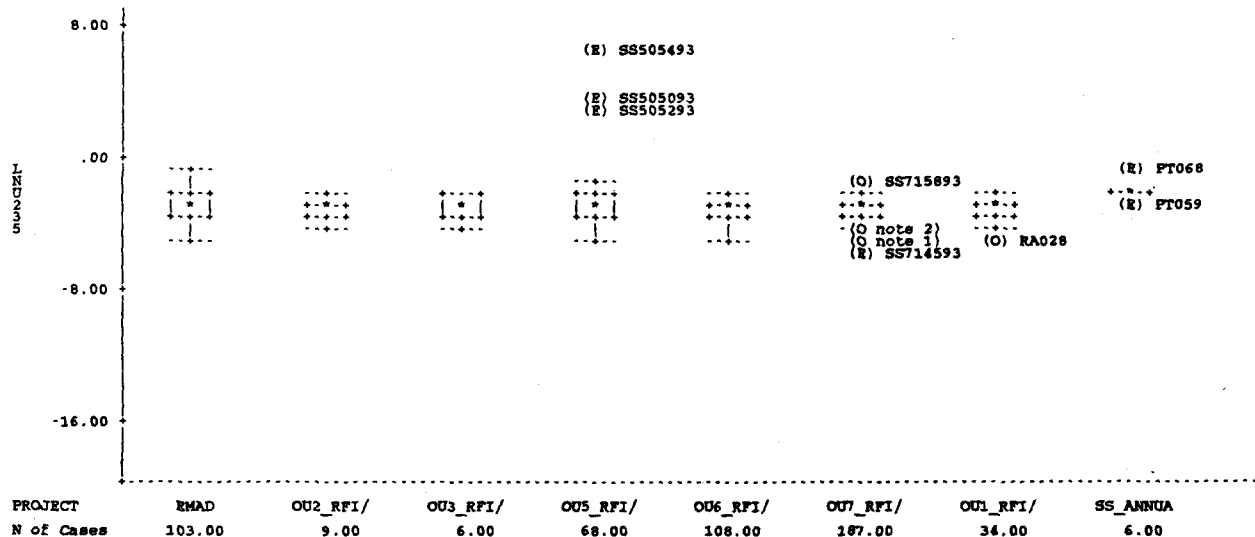
Selenium (mg/kg) by Soil Type/Study



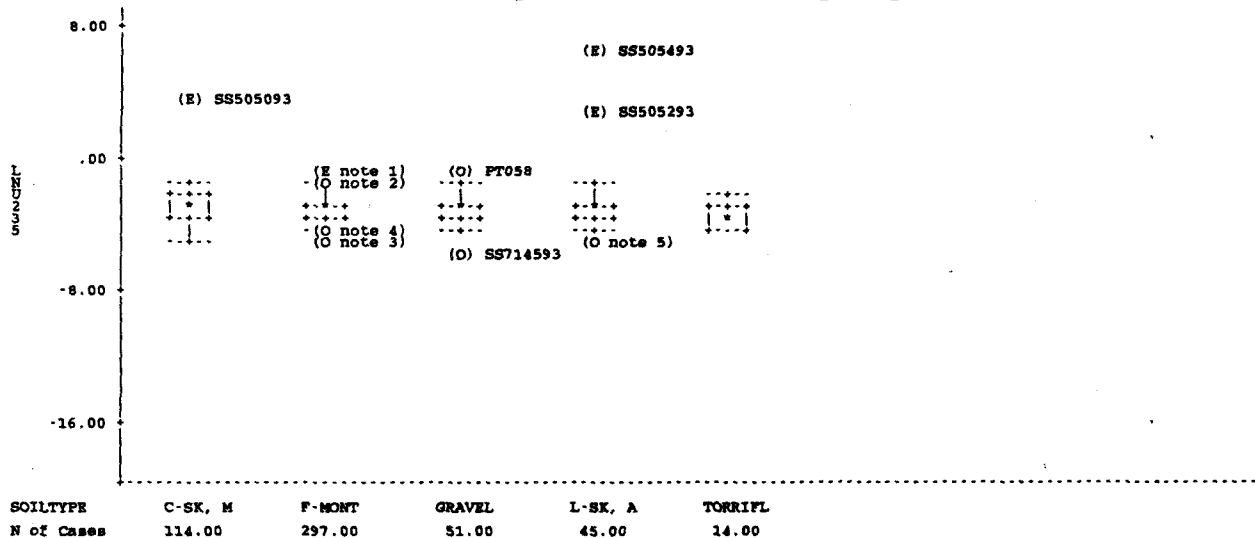
Natural Log of Uranium-235 (pCi/g)



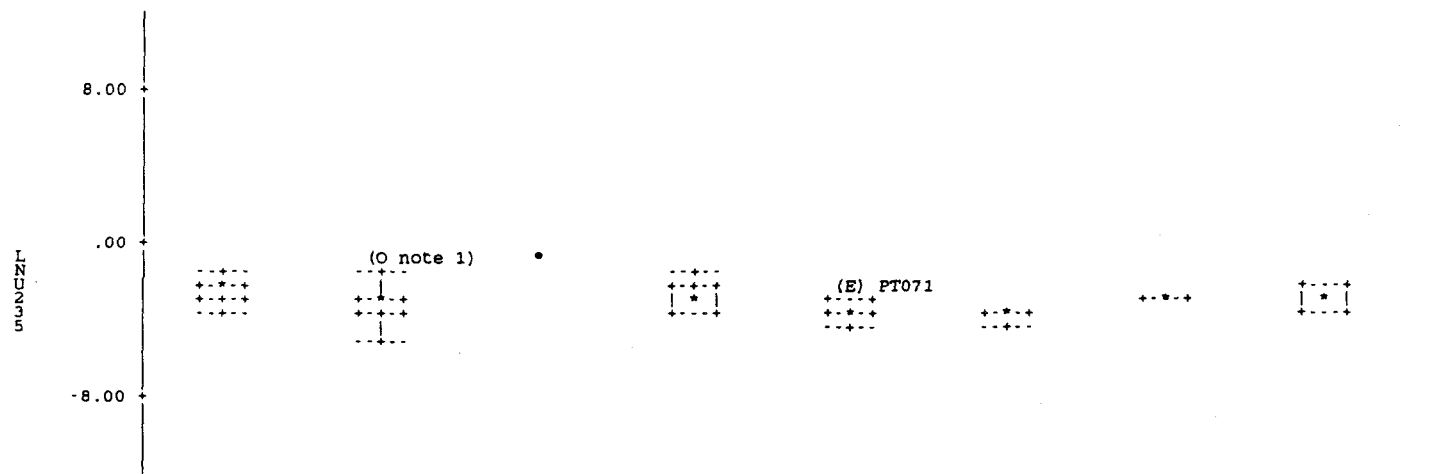
Natural Log of Uranium-235 (pCi/g) by Study



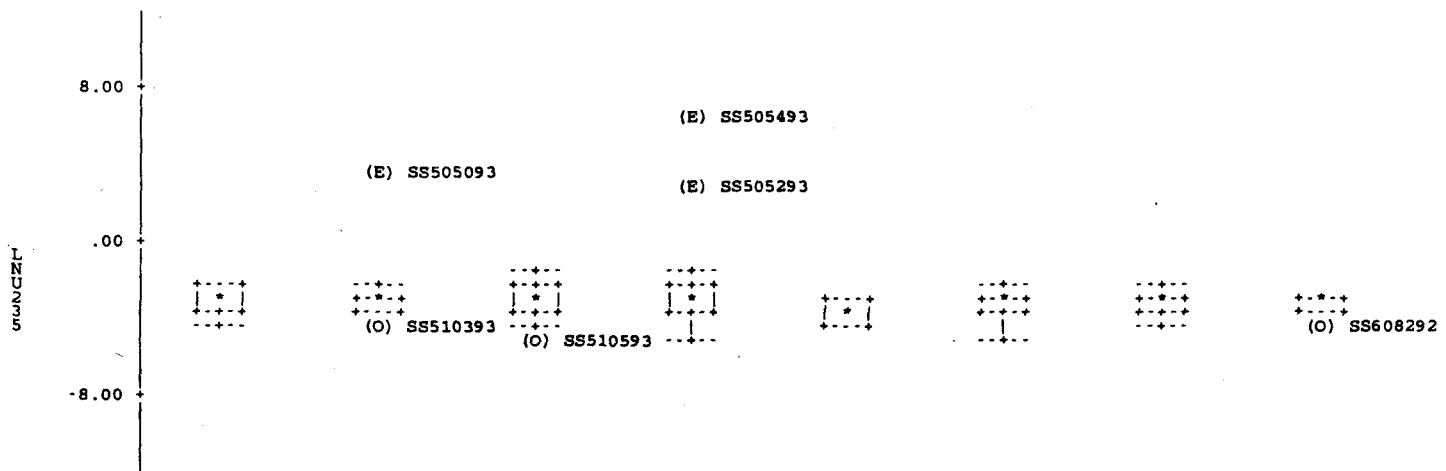
Natural Log of Uranium-235 (pCi/g) by Soil Type



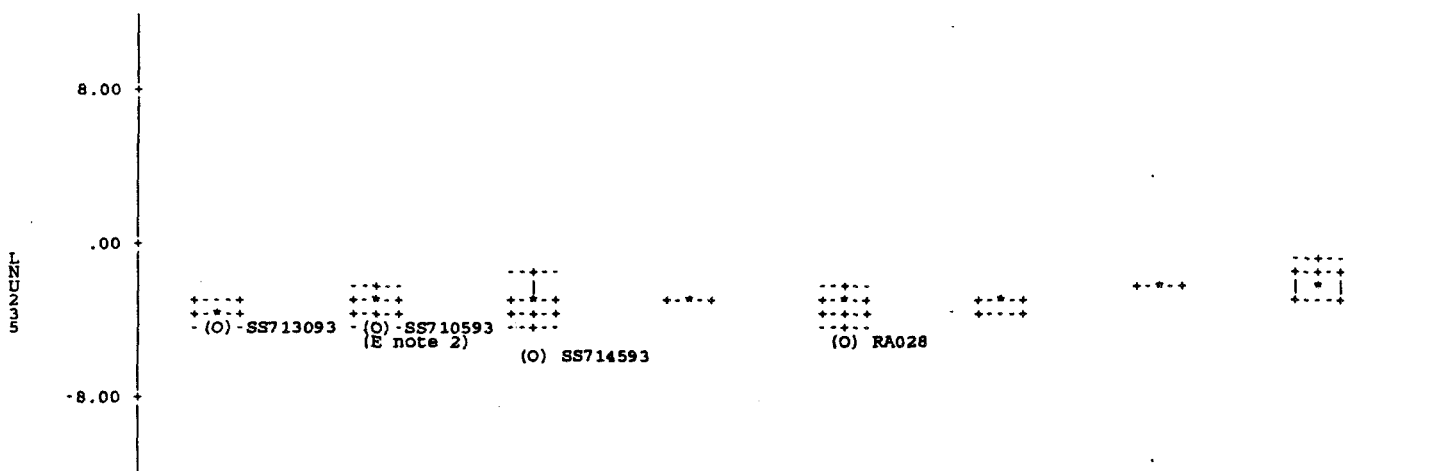
Natural Log Uranium-235 (pCi/g) by Study/Soil Type



| PROJECT SOILTYPE | EMAD C-SK, M | EMAD F-MONT | EMAD GRAVEL | EMAD L-SK, A | EMAD TORRIFL | OU2 RFI/ C-SK, M | OU2 RFI/ F-MONT | OU2 RFI/ L-SK, A |
|------------------|--------------|-------------|-------------|--------------|--------------|------------------|-----------------|------------------|
| N of Cases | 25.00 | 65.00 | 1.00 | 7.00 | 5.00 | 3.00 | 2.00 | 4.00 |

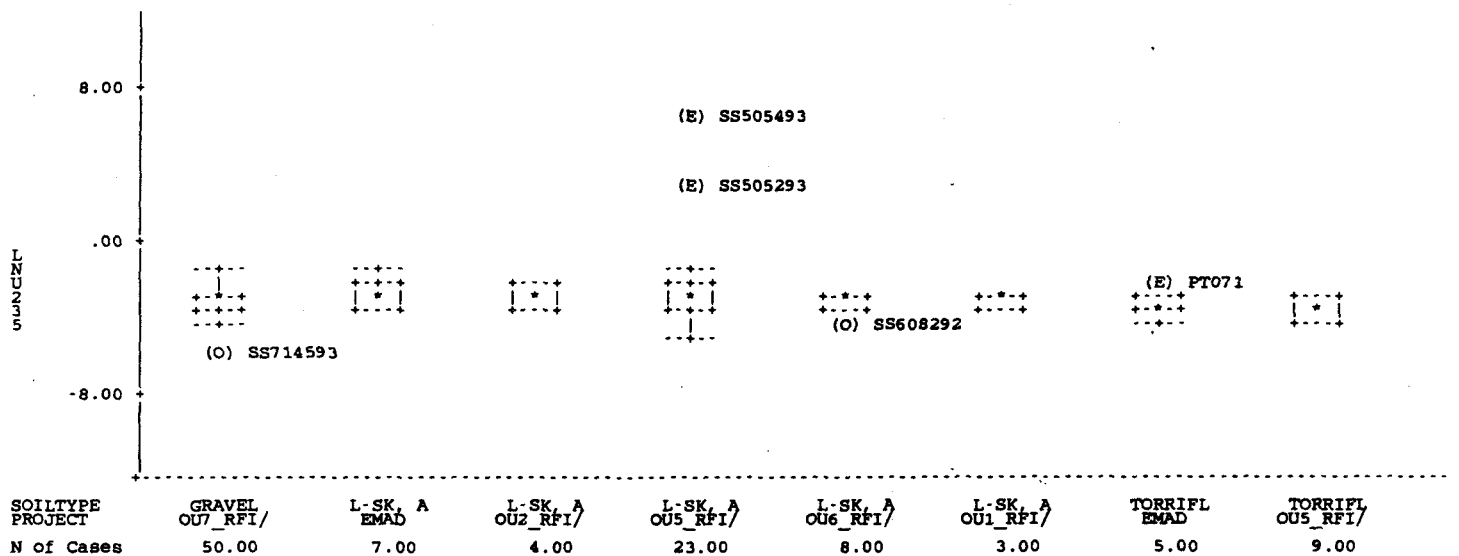
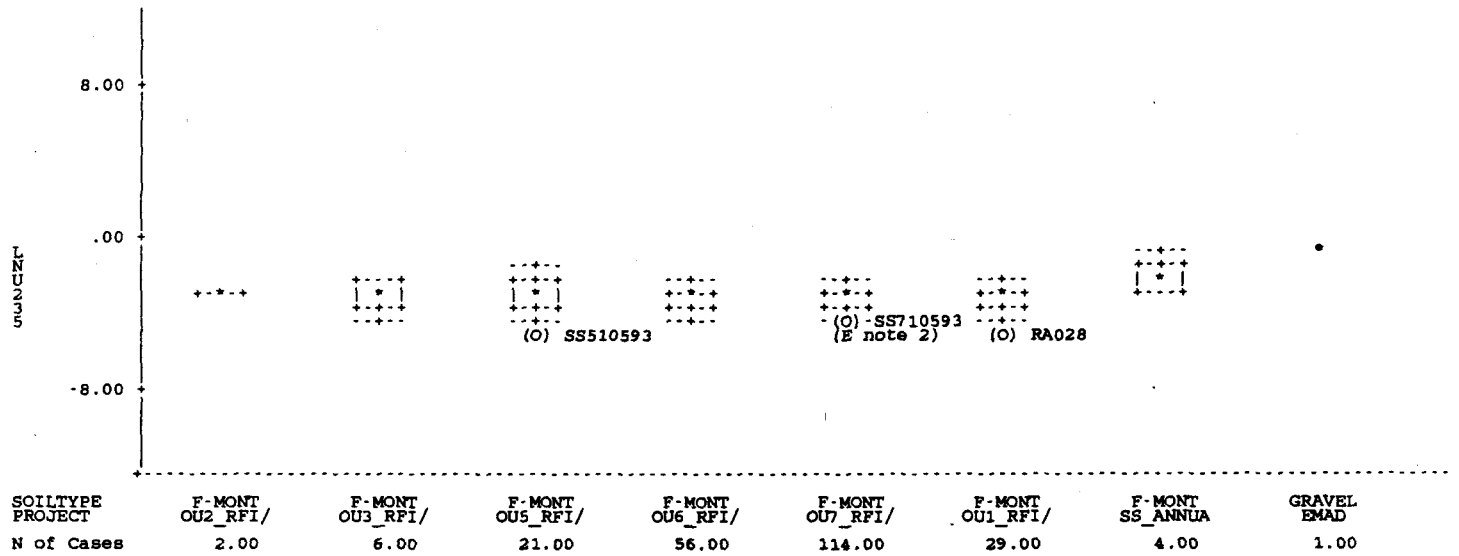
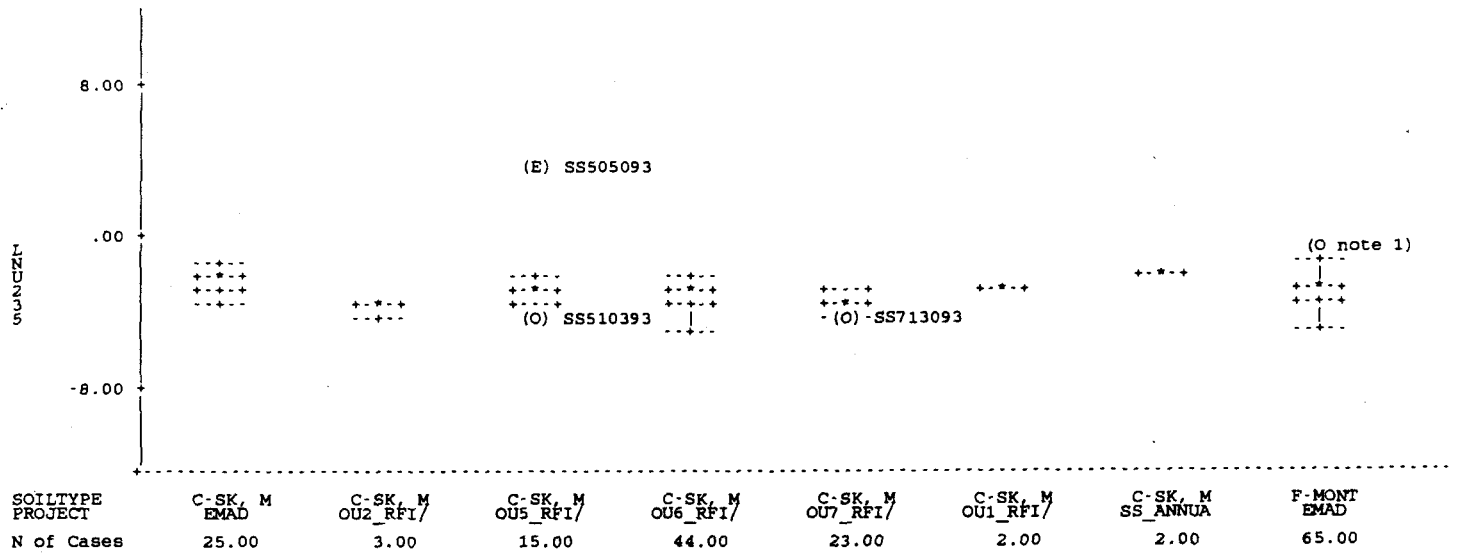


| PROJECT SOILTYPE | OU3 RFI/ F-MONT | OU5 RFI/ C-SK, M | OU5 RFI/ F-MONT | OU5 RFI/ L-SK, A | OU5 RFI/ TORRIFL | OU6 RFI/ C-SK, M | OU6 RFI/ F-MONT | OU6 RFI/ L-SK, A |
|------------------|-----------------|------------------|-----------------|------------------|------------------|------------------|-----------------|------------------|
| N of Cases | 6.00 | 15.00 | 21.00 | 23.00 | 9.00 | 44.00 | 56.00 | 8.00 |



| PROJECT SOILTYPE | OU7 RFI/ C-SK, M | OU7 RFI/ F-MONT | OU7 RFI/ GRAVEL | OU1 RFI/ C-SK, M | OU1 RFI/ F-MONT | OU1 RFI/ L-SK, A | SS ANNUA C-SK, M | SS ANNUA F-MONT |
|------------------|------------------|-----------------|-----------------|------------------|-----------------|------------------|------------------|-----------------|
| N of Cases | 23.00 | 114.00 | 50.00 | 2.00 | 29.00 | 3.00 | 2.00 | 4.00 |

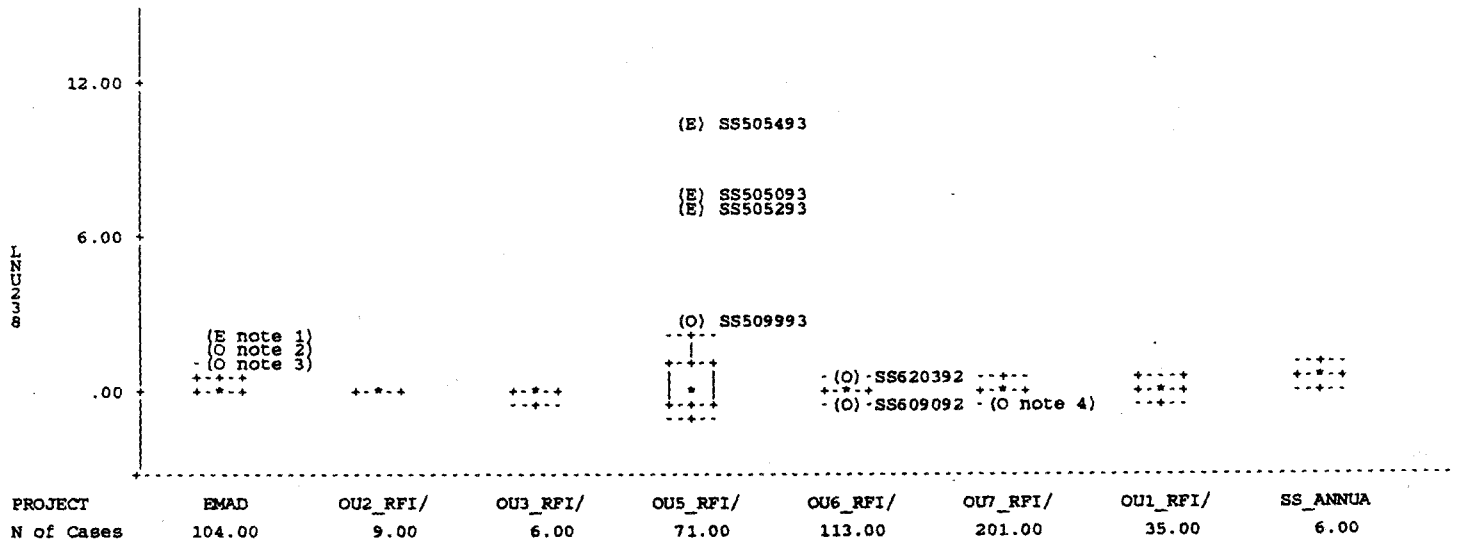
Natural Log of Uranium-235 (pCi/g) by Soil Type/Study



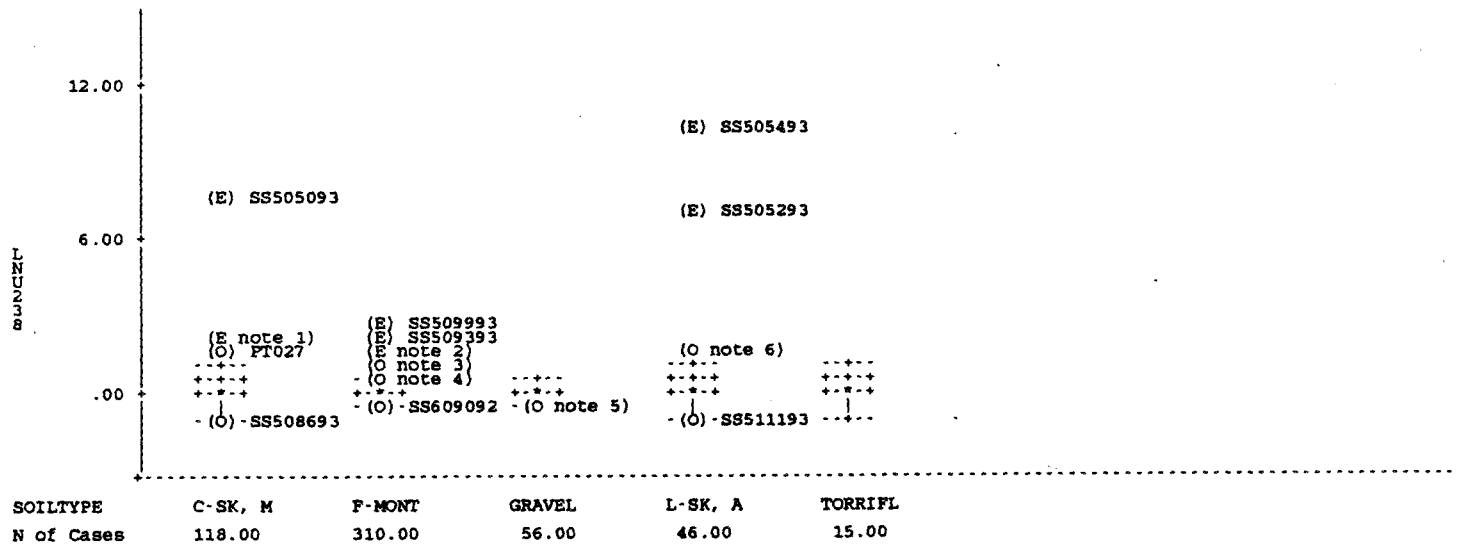
Natural Log of Uranium-238 (pCi/g)



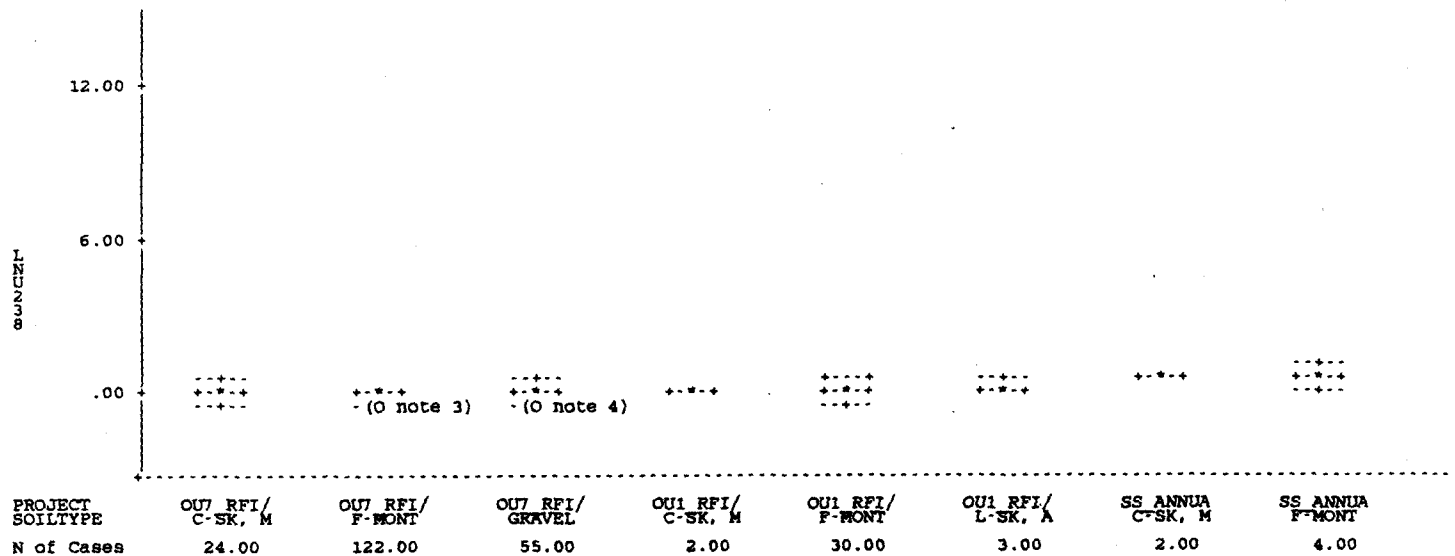
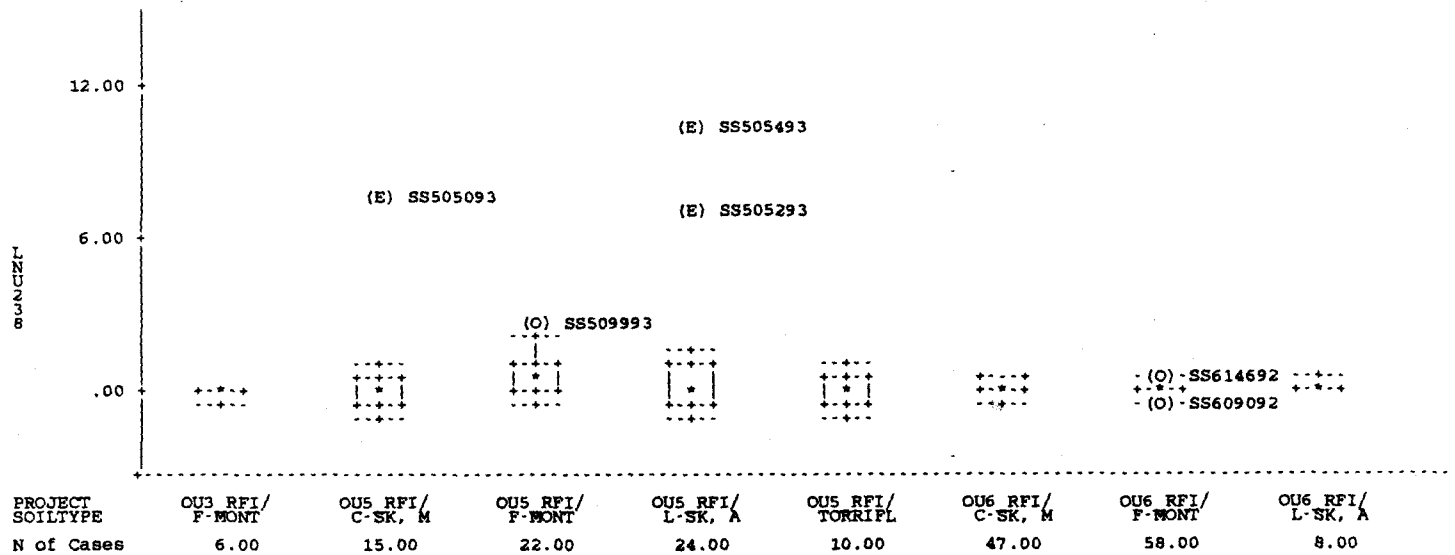
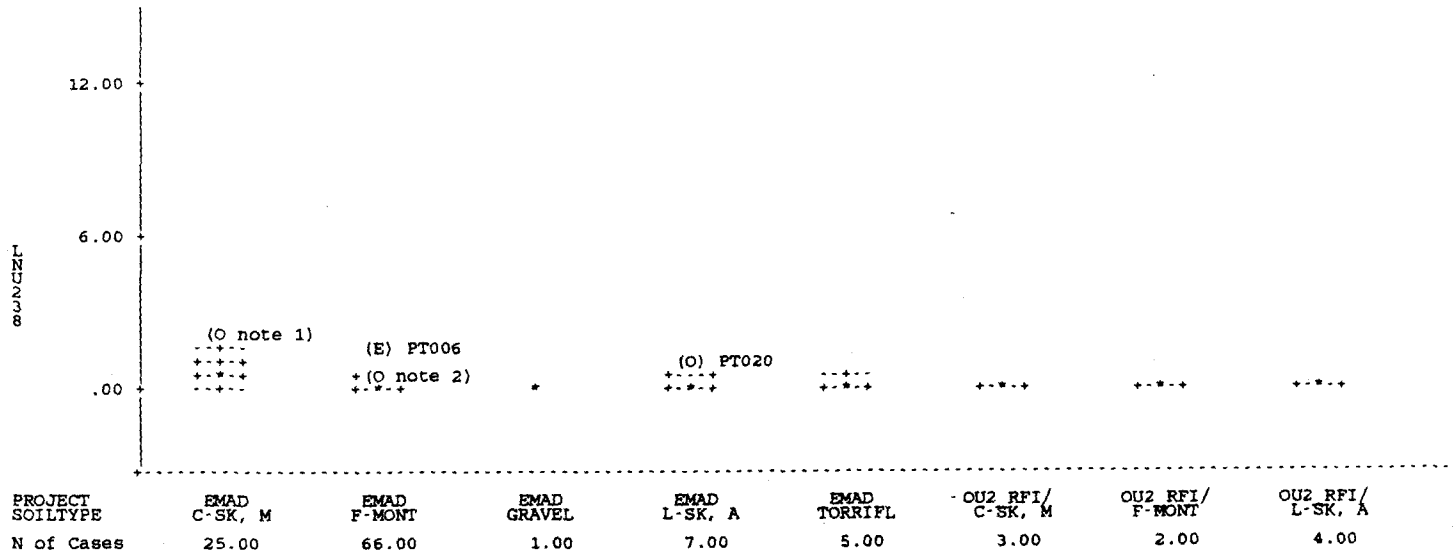
Natural Log of Uranium-238 (pCi/g) by Study



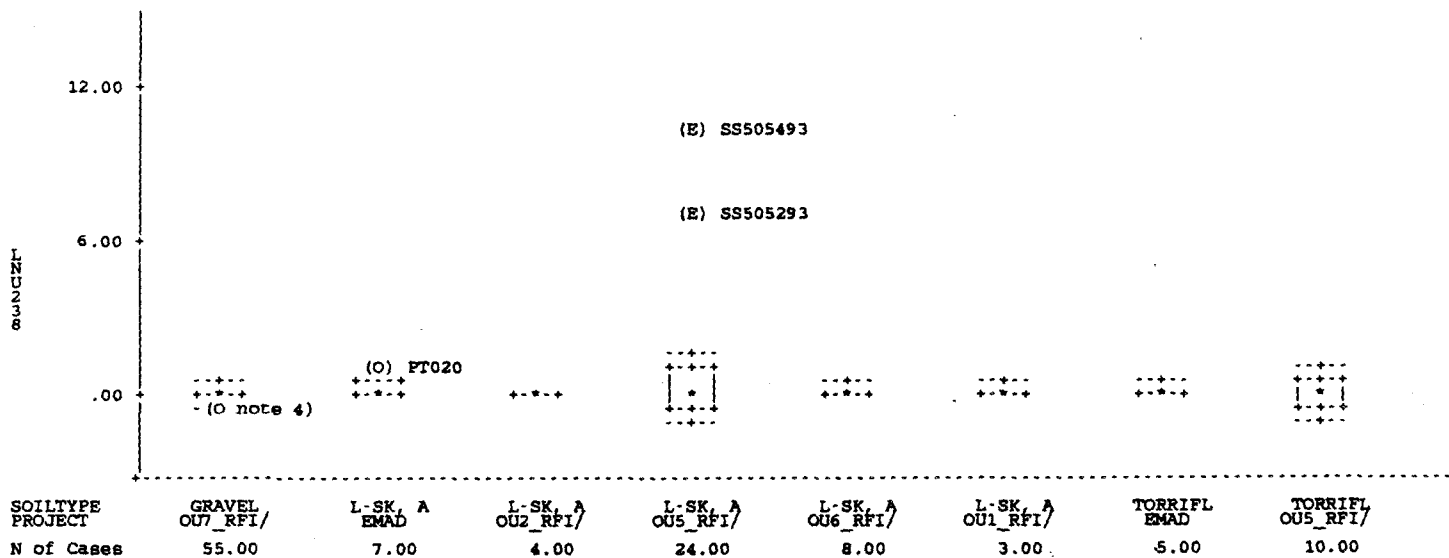
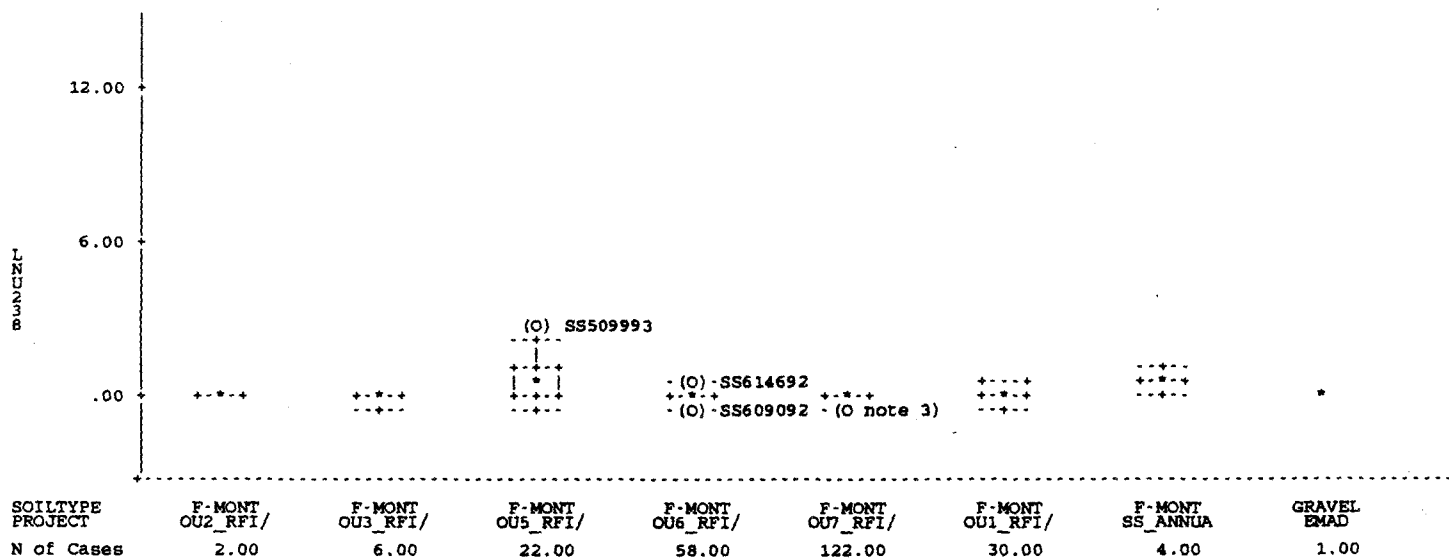
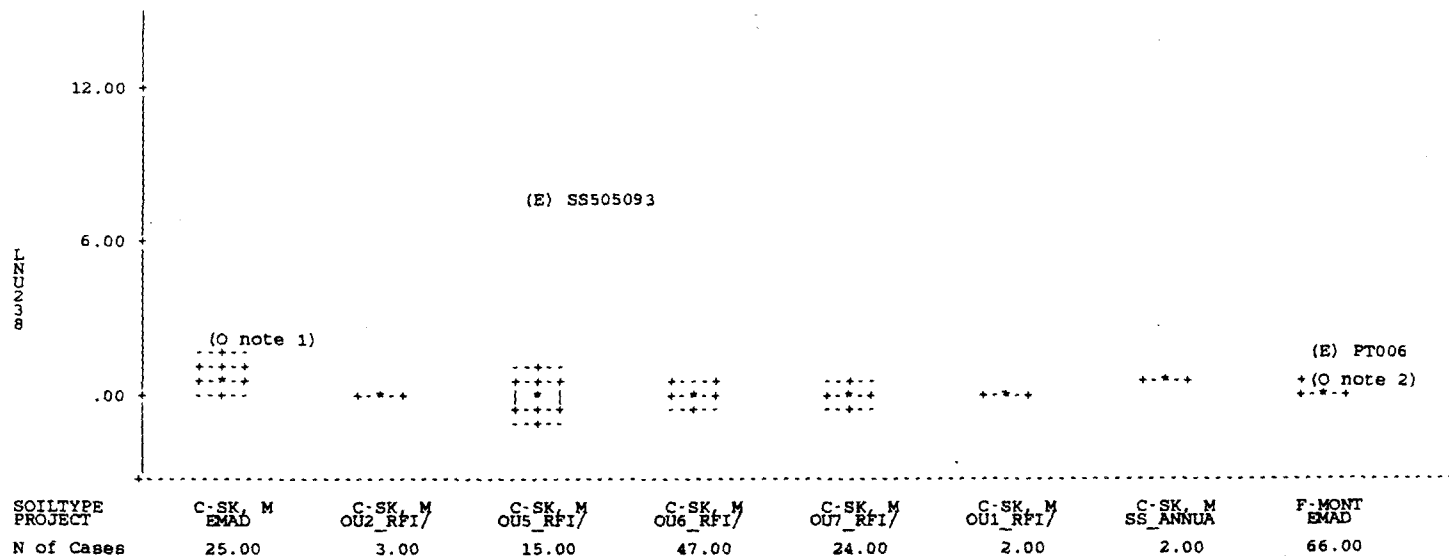
Natural Log of Uranium-238 (pCi/g) by Soil Type



Natural Log of Uranium-238 (pCi/g) by Study/Soil Type



Natural Logarithm of Uranium-238 (pCi/g) by Soil Type/Study





APPENDIX D
DATA TREATMENT METHODOLOGIES



APPENDIX D

DATA TREATMENT METHODOLOGIES

Appendix D summarizes data treatment methodologies that will be utilized by the BSCP.

CLASSIFICATION OF NON-DETECTS

The manner in which analytical results are classified as non-detects is dependent upon the analyte group. The following discusses non-detect classification for radionuclides, organics, and inorganics.

- All data for radionuclides should be used as detects, except for rejected data (Validation = R).
- For organics, the result qualifier (entered in the Qualifier field) should be used to determine the percentage of non-detects. Non-detects for organic analytes are generally qualified "U", but other designations may also appear in the result-qualifier field.

Positive detections (i.e., "hits") of some common laboratory contaminants such as acetone, methylene chloride, and certain phthalates may indicate contamination if detected in the associated laboratory blank; such sample results are designated as a "B" in the Qualifier field. EPA guidance for data validation and risk assessment (EPA, 1989a) indicates that if the concentration of a common lab contaminant in a sample is more than 10 times the concentration of the sample analyte in the associated blank, then the sample result is taken to be real (i.e., a "hit"), not attributable to laboratory contamination. For other analytes that are not typically found as laboratory contaminants, EPA guidance (EPA, 1989a) states that if the concentration in the sample exceeds five times the concentration in the associated blank, then the sample result is taken to be real, not attributable to laboratory contamination.

- For metals and other chemical parameters (inorganics), it may be ineffective to rely on the result qualifier alone. The following criteria have been employed to differentiate detects from non-detects, and are suggested as guidelines for the data:

- If the Qualifier field contains a "U", the result is used as a non-detect (i.e., censored data point).
- If the Qualifier field is blank and the result is greater than the reported detection limit, the result is used as a detected value, barring evidence to the contrary.
- If the Qualifier field (for inorganics) contains a "B", which indicates that the result was above the instrument detection limit (IDL) but below the contract required detection limit (CRDL), the result is used as a detected value.
- Other characters may also be found in the Qualifier field, and, barring any other evidence to the contrary, these are generally accepted as detects.

All data should be reviewed graphically (non-detects and detects together) prior to the application of any statistical tests. This helps to illustrate any potential problems, such as high-value non-detects (e.g., non-detect values reported as the value of the CRDL). If questions arise, EG&G will give guidance to the subcontractor after jointly reviewing the graphical presentations of the data.

PERFORMING DATA CLEANUP

"Data cleanup" of RFEDS output is a task to make the data consistent. This consists of a time-consuming series of steps (which should be documented by the data user) including the standardization of units, standardization of geologic codes, standardization of locations if the location designation has changed over time, standardization of analyte names (usage has changed over the years), deletion of blank "form-generated" records for which no results are given, exclusion of QC data (rinsates, etc.) from the working data set, removal of any rejected (Validation field = "R") data, replacement of non-validated records with corresponding validated records (if available), correction of incorrect units (e.g., pH should have "PH" as the unit, *not* "MG/L" as the unit), treatment of DUP/REAL pairs, appropriate use of diluted (DIL) results, outlier analysis, etc.

Upon receipt of RFEDS data, the user should verify the field positions of all variables in the RFEDS ASCII output file. After verification, the ASCII file may be transformed into data fields

for a specific software (e.g., SAS, Lotus, Excel, SPSS, etc.) to be used in the data manipulation. It is recommended that the user create successive generations of the data files rather than just continually updating the original data file; this simplifies data analysis if back-tracking is required for any reason. To create successive generations of data files, the following procedure may be used.














1. Create original data files from RFEDS ASCII files; these files contain the entire RFEDS data pull, including QC samples, rejected data, etc.
2. In the second generation of data files, drop QC samples (except DUPs of DUP/REAL pairs), rejected data, blank form-generated records, tentatively identified compounds (TICs), etc.

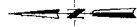
In the RFEDS output format (i.e., for data extracted after February 21, 1994), the validated results, units, qualifiers, and detection limits will automatically replace the lab results, units, qualifiers, and detection limits. The validation code field ("Validation") indicates whether the datum is acceptable (Validation = A, V, or JA), or rejected (Validation = R), or other.

3. Treat results from samples requiring dilution individually. Treatment of DIL data requires the data analyst to find the analyte(s) that necessitated the dilution; these should have a qualifier of "E" (for exceedance of calibration range). The DIL results(s) for the E-qualified analyte(s) should be used in the data analysis; other analytes may have results reported for the DIL sample analysis, but these results should be deleted if these analytes in the original undiluted sample were NOT qualified as "E".
4. Standardize location names and soil units. Standardization of analyte names and units are automatic in the RFEDS data output.
5. From the second generation of data fields created in Steps 2, 3, and 4, create a third generation of data file with averaged DUP/REAL pairs (change REAL value to the mean value of the averaged DUP/REAL pair, then delete the DUP record). In the case of DUPs with no corresponding REAL record, change "DUP" to "REAL". (NOTE: Prior to averaging DUP/REAL pairs, sort the data by LOCATION, SAMPLE NUMBER, SAMPLE DATA, and ANALYTE. This should bring together all existing DUP/REAL pairs).

6. From the data files created in Step 1, create a separate field with QC data for analysis of data quality. Check the precision and accuracy parameters including RPD for DUP/REAL pairs and bias from field or laboratory blanks. Assess completeness by calculating percent completeness of valid and invalid (validation code = R) data point.

ROCKY FLATS PLANT
SOIL MAP UNITS

- | | |
|---|--------------------------------------|
|  | Dover-Kitch-Milway clay loam |
|  | Englewood clay loam |
|  | Fallons very stony sandy loam |
|  | Heaven loam |
|  | Layden-Pinner-Sunbury clay clay loam |
|  | McClure clay loam |
|  | Milway clay loam |
|  | Nederland very cobby sandy loam |
|  | Nunn clay loam |
|  | Pls. gravel |
|  | Rock outcrop, Sedimentary |
|  | Valmont clay loam |
|  | Wilkesman-Layden cobby loam |



Scale = 1 : 20,000
1 inch = 1,660 feet



State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD27

Prepared by:

EG&G ROCKY FLATS

Rocky Flats Plant
P.O. Box 464
Golden, Colorado 80402-0464







Date: April 24, 1984

FIGURE 2-7



U.S. Department of Energy
Rocky Flats Plant

SOIL TAXONOMIC GREAT GROUPS

-  1, mont Argiustolls and similar
-  c-sk, mont, maste, Aridic, Paleustolls
-  Torrifluvents, Haplaquolls, and similar
-  l-sk, Aridic Argiustolls and similar
-  Pts, gravel
-  Rock outcrop, Sedimentary



Scale = 1 : 20,000
1 inch = 1,667 feet



State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD27

Prepared by:

EG&G ROCKY FLATS

Rocky Flats Plant
P.O. Box 464
Golden, Colorado 80402-0464

Date: April 26, 1984

FIGURE 2-8

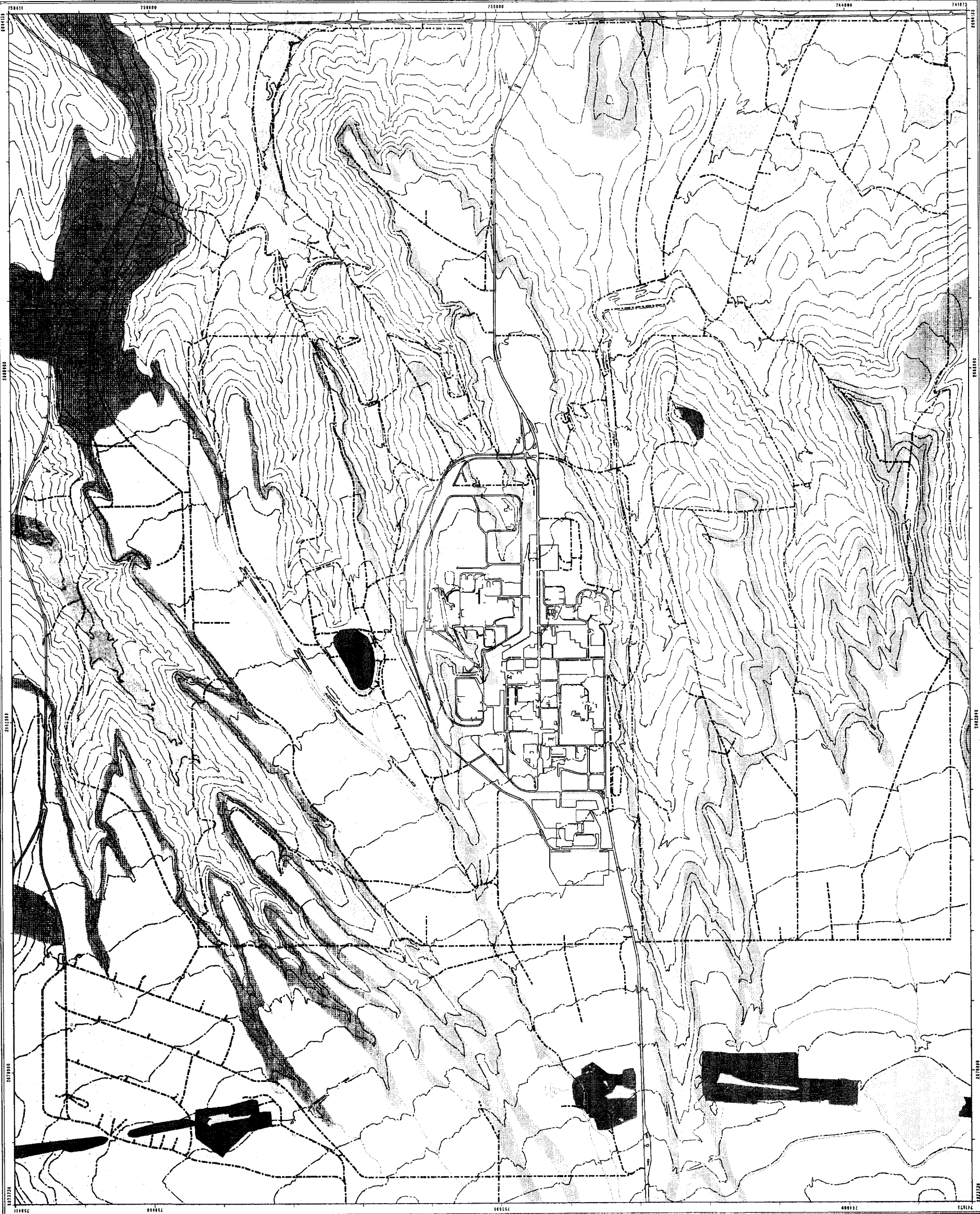




FIGURE 4-7

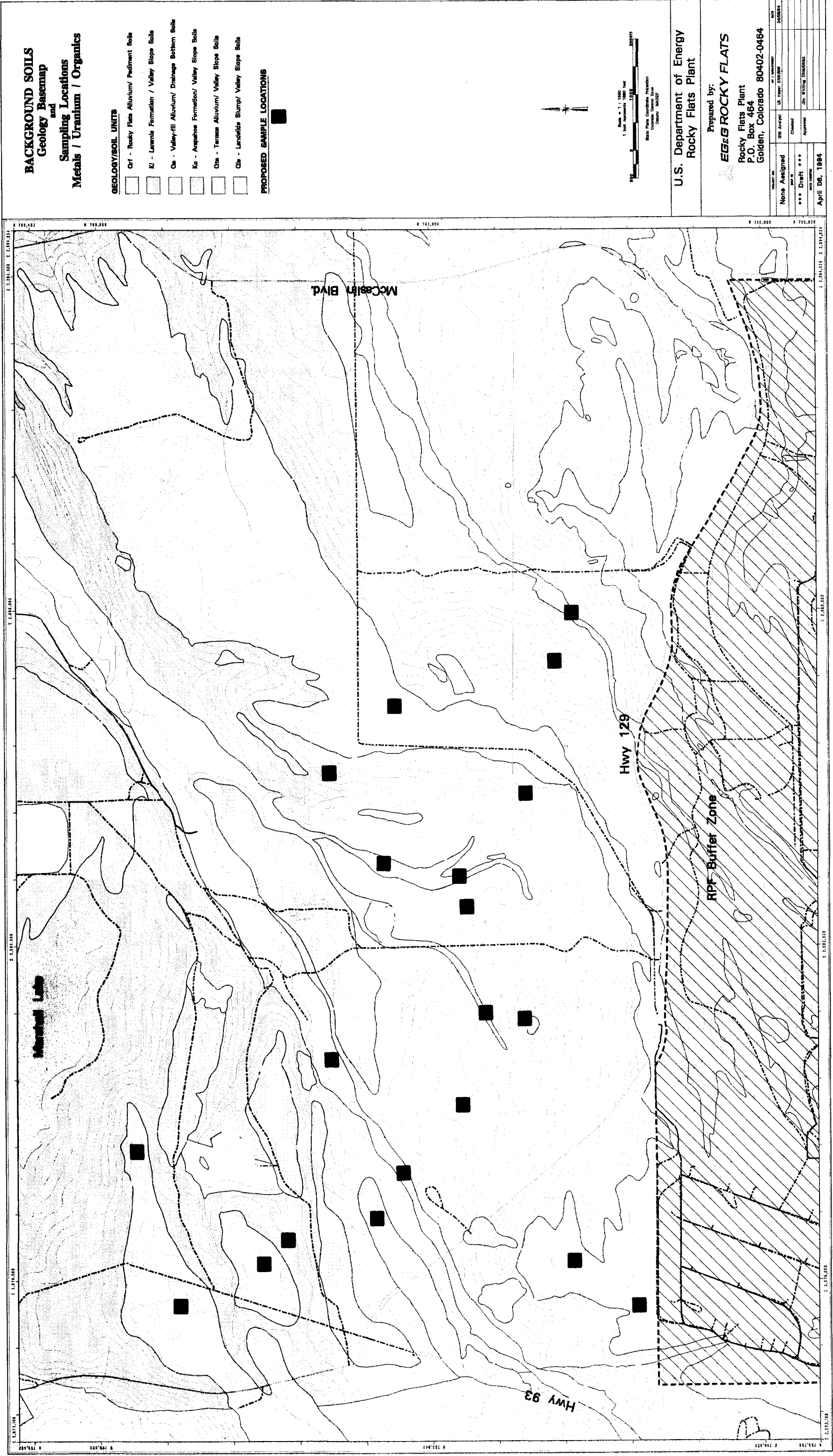


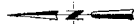
FIGURE 5-3

SOIL TAXONOMIC
GREAT GROUPS

- f, mont Argilustolls and similar
- c-ek, mont, mesic, Aridic, Paleustolls
- Torrifluvents, Haplaquolls, and similar
- l-ek, Aridic Argilustolls and similar
- Pits, gravel
- Rock outcrop, Sedimentary

PIT LOCATIONS

PREVIOUS STUDIES
PROPOSED PROFILES



Scale = 1 : 20160
1 inch = 1680 feet



State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD27

Prepared by:

EG&G ROCKY FLATS

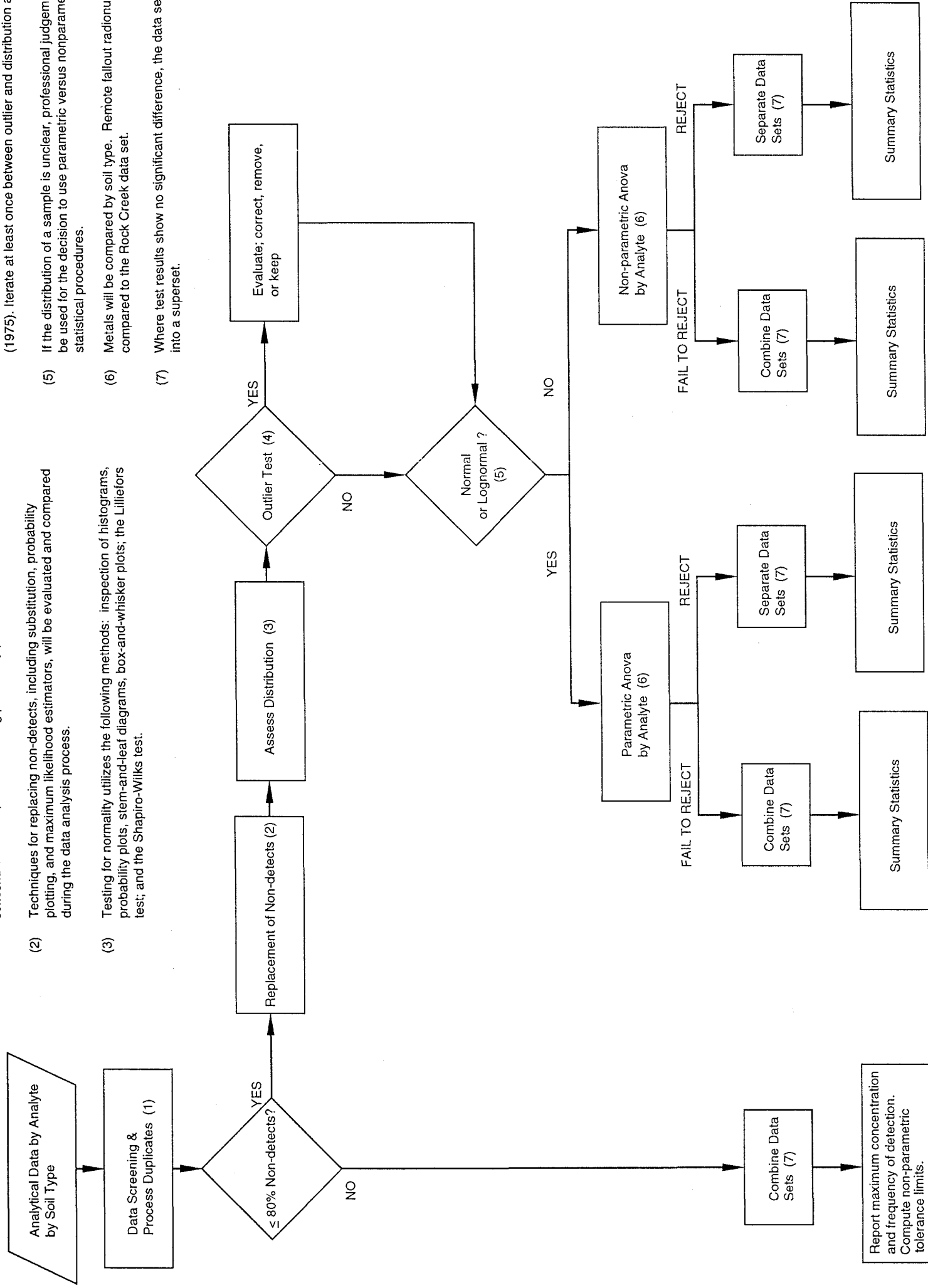
Rocky Flats Plant
P.O. Box 464
Golden, Colorado 80402-0464

Date: April 08, 1984

FIGURE 5-5

NOTES:

- (1) Data screening consists of inspections and logic checks of the raw data set, including fixing data entry errors, checking extreme values, checking concentration units, and examining probability plots.
- (2) Techniques for replacing non-detects, including substitution, probability plotting, and maximum likelihood estimators, will be evaluated and compared during the data analysis process.
- (3) Testing for normality utilizes the following methods: inspection of histograms, probability plots, stem-and-leaf diagrams, box-and-whisker plots; the Lilliefors test; and the Shapiro-Wilks test.
- (4) Outliers in the data sets will be evaluated with probability plots, box-and-whisker plots, and histograms. Single outlier tests will follow Dixon (1953) or ASTM (1975). Multiple outlier tests will follow Rosner (1975). Iterate at least once between outlier and distribution assessment.
- (5) If the distribution of a sample is unclear, professional judgement will be used for the decision to use parametric versus nonparametric statistical procedures.
- (6) Metals will be compared by soil type. Remote fallout radionuclide samples will be compared to the Rock Creek data set.
- (7) Where test results show no significant difference, the data sets are combined into a superset.



PREPARED FOR
U.S. DEPARTMENT OF ENERGY
ROCKY FLATS PLANT
GOLDEN, COLORADO

FIGURE 6-1
METHODOLOGY FOR
COMPUTATION OF
BACKGROUND STATISTICS

Surface Soil Locations
Metals Analysis Requested
Buffer Zone Map
25' Locations not surveyed
DRAFT

EXPLANATION

- Surface Soil Locations

Standard Map Features

- Buildings or other structures
- Lakes and ponds
- Streams, ditches, or other drainage features
- Fences
- Rocky Flats boundary
- Paved roads
- Dirt roads

DATA SOURCE: Feature data, including buildings, roads, and fences provided by Rocky Flats Plant, Inc. - 1991. Hydrology provided by USGS (H) - 1991.

Scale = 1:1015,47
1 inch = approximately 617 feet

State Plane Coordinate Projection
Central Meridian: 105° 00' 00" W
Datum: NAD83

U.S. Department of Energy
Rocky Flats Plant

Prepared by:
EG&G ROCKY FLATS
Rocky Flats Plant
P.O. Box 464
Golden, Colorado 80402-0464

MAP ID: 100114

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